ASPECTS OF THE FEEDING ECOLOGY OF THE BANDICOOTS, *Perameles gunnii* (GRAY 1838) and *Isoodon obesulus* (SHAW AND NODDER 1797) (MARSUPIALIA:PERAMELIDAE) IN SOUTHERN TASMANIA

by

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ABSTRACT

An investigation was undertaken into the diet and comparative feeding ecology of the Tasmanian Bandicoots, *Perameles gunnii* and *Isoodon obesulus affinis*. Studies on captive specimens revealed that both *P. gunnii* and *I. obesulus* detected significantly more cups containing ground cockroach extract than non-extract cups buried at various depths. However, only *P. gunnii* located significantly more cups containing earthworm extract than non-extract cups. Auditory trials demonstrated that *P. gunnii* and *I. obesulus* do not appear to depend on hearing to locate prey. Olfaction appears to be the primary prey detection strategy employed by bandicoots.

Digestibility trials revealed that soft-bodied prey such as earthworms may be totally digested, hence appear absent in bandicoot faeces. Soft-bodied insects e.g. cockroaches, although identifiable in faeces, are difficult to quantify due to the digestive fragmentation of potentially quantifiable structures.

From their diet in southern Tasmania, *P. gunnii* and *I. obesulus* appear to be qualitatively opportunistic omnivores, feeding on a wide range of prey available, but apparently not always in proportion to which they occur. The overlap in 36 prey categories is positively correlated for each of the Peramelids with only two taxa showing significant differences in the total diets between the two species. Significantly more *I. obesulus* scats than *P. gunnii* samples were collected containing bees and wasps (Hymenoptera); significantly more *P. gunnii* faeces were obtained containing Clover (*Trifolium repens*). The diet would largely appear to reflect seasonally and locally abundant food items.

The most important dietary items for *I. obesulus* in autumn appeared to be ants (Formicidae), maggots (Calliphoridae larvae), Rove beetles (Staphylinidae), mature Coleopterans, Scarabaeidae larvae, Hymenopterans and Hemipterans, while those of *P. gunnii* were larvae, spiders (Araneae), flies (mature Diptera), Calliphoridae larvae, ants, ground beetles (Carabidae) and their larvae. Blackberries, Monocot and a Zygomycete fungus were important plant components in faecal

pellets of both species, and Moss and nodules in *P. gunnii*.

Two faecal pellets in winter for *P. gunnii* revealed Scarabaeidae larvae, Calliphoridae larvae, armyworms (Noctuidae), Springtails (Collembola) in half of the sample while Clover root nodules and seeds occurred in both scats. In *I. obesulus*, Scarabaeidae larvae, ants, Carabidae larvae, mature Coleoptera, seeds, Monocot, nodules and Gasteromycete fungus occurred in more faecal pellets for the winter session than other prey taxa.

In spring, a marked increase in E/S/C larvae correlated with an increase in this category in the faeces of both bandicoot species. Corbie grubs (Hepialidae), spiders, Rove beetles, Monocot, seeds and Clover root nodules occurred in more scats of *I. obesulus*, relative to other taxa. For *P. gunnii*, armyworms appeared to be most important with larvae, Mites (Acarina), Scarabaeidae larvae, mature Coleoptera, Monocot, seeds and roots.

Slight diet differences were observed between habitats for *I. obesulus* and appeared to reflect the local availability of prey items.

Prey size selection indicated that *I. obesulus* and *P. gunnii* appear to take a similar size of prey (approximately 11-11.5 mm); however the number of samples recorded for *P. gunnii* was small. No correlation appeared to exist between predator weight (*I. obesulus*) and mean prey size as determined by regression equations relating insect tarsal widths from faeces to those of insects of a known length. Bimodal capture-success-curves were recorded for *I. obesulus* possibly due to the inclusion of elongate Rove beetles and small prey (1-2 and 2-3 in winter) when larger prey appeared to decrease in availability. However, *I. obesulus* predominantly selected larger size classes of prey than those available.

Diet does not seem to be a significant factor in the apparent spatial, ecological separation exhibited by the two Peramelid species. Temporal segregation may be additionally important in reducing competition between *I. obesulus* and *P. gunnii*.

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CHAPTER 1

INTRODUCTION

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INTRODUCTION

1.1 Introduction to the Families Peramelidae and Thylacomyidae

The bandicoots are currently divided into two families, the Peramelidae and Thylacomyidae (Kirsch and Calaby 1977), comprising eight genera and 20 species. Five genera once occurred on the Australian mainland, two of which are represented in Tasmania. The remaining genera are restricted to New Guinea and surrounding islands. Four genera, *Perameles*, *Isoodon*, *Chaeropus* and *Thylacomys* are Australian (Lyne 1964b). *Chaeropus* is represented by a single species now believed extinct (Aitken 1979). *Echymipera* is primarily New Guinean but is represented by a subspecies in north Queensland (Gordon and Lawrie 1977). The popular name "bandicoot" is a derivative from the Telugu language of India, meaning "pig-rat". The term was originally applied to a large species of rodent, *Bandicota indica* (*B. bengalensis*), occurring in India and Sri Lanka (Walker 1964).

Bandicoots are small, rat to rabbit sized marsupials, weighing 1-2 kg when mature (Lyne 1964b; Stodart 1977). They are classified by two anatomical features:

(1) Their polyprotodont dentition (many incisored teeth) is comparable to and characteristic of the carnivorous and/or insectivorous marsupials (Family Dasyuridae);

(2) The partial fusion of the second and third digits of the pes (syndactylous toes), is a condition characteristic of the herbivorous groups of the Family Macropodidae.

Their herbivorous/insectivorous dietary habits are reflected in the intermediate nature of these two anatomical structures (Morrison 1946; Rayment 1954; Marshall 1972). With regards to the second anatomical feature, only the terminal joints and claws of the digits are free, while the fourth toe is enlarged. This specialised structure is thought to function as a hair comb removing a large number of ectoparasites

e.g. fleas, mites and ticks infesting the animal's hair (Wood-Jones 1924). The incisors remove material adhering to the combined toes (Heinsohn 1966).

The forefeet of all bandicoot genera (except *Chaeropus*) have five digits. Generally two or three of the middle digits are long, functional and strongly clawed for excavating in the soil in search of invertebrates and vegetable matter. The first and fifth digits are vestigial (Thomas 1888; Walker 1964). The only 2 functional digits present in *Chaeropus* are the second and third while the fourth is rudimentary and the first and fifth absent (Wood-Jones 1924; Lyne 1952). Digging actions are carried out by rapid backward scratching of the forepaws removing potential food items which are quickly devoured by the probing, pointed snout. Excavations are usually conical in shape to accommodate the snout. Digging is discontinued while larger prey items are consumed and unfamiliar objects may be vigorously rolled and kneaded (Wood-Jones 1924; Heinsohn 1966).

Rayment (1954) considers the omnivorous diet is indicated by the bandicoot's dentition. The five upper incisors are flattened and arranged in a group of four around the arc of the front of the mouth, the fifth tooth lying some distance behind it. They are unequal in size and the three lower incisors are almost horizontal and to the extreme anterior of the jaw, an adaptation for raising objects out of the soil. The crown of the last lower incisor has two lobes, a character unique to bandicoots. The canines are slender and pointed, and separated by gaps between the incisors and premolars. The premolars are of similar structure to the canines, and the molars are triangular in outline with four external cusps. The dental formula is $i\frac{5}{3}$, $c\frac{1}{1}$, $p.m.\frac{3}{3}$, $m\frac{4}{4}$ (Walker 1964; Stanbury 1970).

The gestation period has been estimated for *Perameles nasuta* (Hughes 1962; Lyne 1964a; Stodart 1966) and *Isoodon macrourus* (Lyne 1974) as approximately 12.5 days. This is the shortest gestation recorded for any mammal (Lyne 1974) and is probably common to all bandicoots, although McCracken (1985) estimated the mean gestation period for the Bilby *Macrotis lagotis* as being 14 days (range 13-16).

Bandicoots are the only marsupials known to possess a chorio-allantoic placenta and implantation is comparable to the eutherian mammals (Hughes 1974). Parturition occurs with the young attached to allantoic stalks, in turn united to the placenta which remains in the uterus. The stalks remain attached to the young until they fuse firmly to one of usually eight teats arranged in two semicircles in a backwardly opening pouch (Lyne 1974). The rear opening pouch presumably prevents material being thrown into the pouch whilst digging (Wood-Jones 1924) although Gordon (1974b) considered it ensures the young the shortest possible journey to the nipples at birth.

Gordon (1974b) summarises the mechanisms enabling bandicoots to achieve a high reproductive output.

(1) Larger litter sizes.

(2) Growth is faster than any other marsupial known (Hulbert 1972; Lyne 1964b, 1974).

(3) Short gestation.

(4) A type of allantoic placenta which apparently enables the short gestation.

(5) Birth of a new litter approximately with the previous litters weaning, enabling rapid litter succession in favourable conditions.

(6) Early sexual maturity [three or four months in some species e.g. *P. gunnii* and *I. obesulus* (Heinsohn 1966); *P. nasuta* (Lyne 1964a); *I. macrourus* (Gordon 1974b)].

Bandicoots are generally socially intolerant and highly pugnacious creatures, living solitary lives. Thomas (1985) considered that stress induced in *I. obesulus* by high population densities may be sufficient to induce intrinsic population regulation mechanisms. Social interactions are restricted to the shortest possible time for a successful mating and mother-offspring interactions (Stodart 1966; Heinsohn 1966; Gordon 1974a). *Isoodon obesulus*, in captivity, will fight with a

member of the opposite sex to death although Moloney's (1982) captive trials revealed that although intraspecific encounters between male conspecifics of both *I. obesulus* and *P. gunnii* were invariably aggressive, interactions between female conspecifics and heterosexual intraspecific interactions generally terminated in mutual avoidance (excluding sexual incidents). Interspecific interactions whether heterosexual or homosexual also were non-antagonistic. Heinsohn (1966) did not observe interspecific encounters between the two species in the wild. Wood-Jones (1924) and Moloney (1982) have described their intraspecific fighting behaviour. Mackerras and Smith (1960) however, maintained a pair of *I. macrourus* together of similar size. Stodart (1966) thought a large enclosure with good ground cover was necessary for two males (*I. macrourus*) to coexist. Captive bilbies (*M. lagotis*) were found to be relatively passive in contrast with other bandicoots. A rigid dominance hierarchy among males was sustained without destructive fighting (Johnson and Johnson 1983).

With respect to the two species involved in the present investigation, *P. gunnii* and *I. obesulus* are biologically very similar. Both species utilise dense vegetation for nest sites constructed of grass, leaves and sticks on the ground surface. Occasionally a shallow hollow is excavated in the ground lined and covered with vegetation. The nest entrance is concealed upon emergence or entry (Ride 1970). Troughton (1965) and Heinsohn (1966) also recorded that *P. gunnii* utilised abandoned rabbit burrows as nest sites. In this study one *P. gunnii* was observed to enter a small hole in the ground adjacent to a root of a Pine tree. The hole was deep as the end of it could not be seen and it did not appear to be a rabbit burrow. *Isoodon obesulus* appears to burrow in Western Australia to avoid excessive water loss (Kirsch 1968). Bandicoots are considered only to drink water in captivity. In the wild, water from food and dew suffices their needs (Walker 1964; Stanbury 1970). However Hulbert (see Gordon 1971) showed that if free water is available in the wild *Isoodon macrourus* will utilise it; however if unavailable, they survived well without it.

Heinsohn (1966) reported that both species in the north-west of Tasmania are nocturnal and when active spend most of the time foraging for food. Some diurnal activity was observed in *I. obesulus*. The

breeding season appeared to be slightly shorter in *I. obesulus* (July to February) than *P. gunnii* (June to March) and seemed to be correlated with food supply in both species (Heinsohn 1966). However in western Victoria *I. obesulus* may breed throughout the year (Stoddart and Braithwaite 1979) as does *P. gunnii* (Seebeck 1979; Lee and Cockburn 1985). In eastern Victoria *I. obesulus* possessed a definite breeding season between August and January (Stoddart and Braithwaite 1979). The gestation, duration of pouch life (approximately 60 days) and average litter size (2.3) is also similar in the two in Tasmania (Heinsohn 1966).

The genus *Isoodon* comprises three species of short-nosed bandicoots. *Isoodon obesulus* is commonly known as the Quenda, Southern Short-nosed or Southern Brown Bandicoot (Braithwaite 1983). Wood-Jones (1924) describes the animal as robust and compact, the pelage being short and harsh due to the presence of spiny, flattened guard hairs. The under-fur is softer, shorter and greyish in colour relative to the guard hairs. The bristle hairs are banded and light at the roots, black or dark brown in the middle and yellow at the tips with some bristle hairs being completely brown. The glossy black and yellow coat of the dorsal and lateral surfaces is obvious at close range, but at a distance a warm brown appearance is perceived. The ventral surface and inner side of the limbs are yellow-grey, the bristle hairs being greyish and under-fur almost white. On handling the animal the fur detaches easily. The eyes are black, ears small and rounded, the rhinarium naked, brown and grooved in the midline (Wood-Jones 1924). The tail is long in comparison with *P. gunnii* (Hyett and Shaw 1980). Linear measurements and weights for *I. obesulus* and *P. gunnii* are provided by Le Souf *et al.* (1926), Braithwaite (1983) and Seebeck (1983) and are listed in Table 1.1.1.

The genus *Perameles* pertains to five species of long-nosed bandicoots of which *P. gunnii* is commonly known as the Eastern Barred, Striped or Gunn's Bandicoot (Seebeck 1983). The fur is a grizzled yellow-brown above (dorsally and laterally) and white to yellow-white ventrally, and on the distal portions of the limbs. A distinct lighter band behind the shoulders passes downwards and backwards uniting with the lighter colour of the ventral surfaces (Le Souf *et al.* 1926). Three or four paler bars associated with the darker hind quarters gives *P. gunnii* its

PLATE 1 *Perameles gunnii*

PLATE 2 *Isoodon obesulus*

TABLE 1.1.1 Various linear body measurements and weights of *I. obesulus* and *P. gunnii*. Range and means (in brackets) presented.

	Isoodon obesulus Sex		Source	*Perameles gunnii* Locality		Source
	Male	Female		Victoria	Tasmania	
Head and body length (mm)	300-360 (330)	280-330 (300)	2	270-350 (310)	270-350 (300)	3
Tail length (mm)	90-140 (120)	90-140 (110)	2	70-110 (94)	70-95 (80)	3
Pes length (mm)	53-59		1	70-72		1
Ear length (mm)	15-21		1	31-34		1
Muzzle to eye (mm)			1	60-65		1
Weight (g)	500-1600 (850)	400-1100 (700)	2	500-900 (660)	500-900 (640)	3

Sources: 1. Le Souf *et al.* (1926)
2. Braithwaite (1983)
3. Seebeck (1983)

descriptive colloquial name (Seebeck 1983). The tail is short and white above with a brown base. The ears are long and pointed and the snout possesses a pink rhinarium. Unlike *I. obesulus*, *P. gunnii* shows little sexual dimorphism with respect to linear measurements and weight (Heinsohn 1966). Hence, only measurements between Victorian and Tasmanian Banded Bandicoots have been provided by Seebeck (1983) and are presented in Table 1.1.1.

Heinsohn (1966) and Moloney (1982) considered *I. obesulus* to be better adapted to densely vegetated areas because of its heavier build and lack of a rapid, bounding motion. In contrast, *P. gunnii* was considered as an open-habitat dweller because of its graceful, slender build and swift bounding movements. Locomotion employs the same four gaits in both species, however *P. gunnii* could achieve higher locomotor rates (Moloney 1982). The high leaping and unpredictable direction changes observed for *P. gunnii* are considered to be a predator evasion

strategy, adapted to open areas because selection of open habitats would probably enhance predator attack (Heinsohn 1966; Moloney 1982).

Homerange in sympatric *I. obesulus* and *P. gunnii* has been investigated in north-west Tasmania by Heinsohn (1966), southern Tasmania by Moloney (1982), while Sampson (1971) looked at homerange in *I. obesulus* in south-west Australia. The three studies concluded that male *I. obesulus* occupy considerably larger homeranges than females. The homeranges occupied by both sexes of *I. obesulus* in north-west Tasmania were considerably larger than those in southern Tasmania. Moloney (1982) attributed this to the encroachment of human settlement on his study sites whereas Heinsohn's (1966) research was conducted on open farm areas. Sampson (1971) recorded considerably larger homeranges for male *I. obesulus* than Heinsohn (1966) but not for females. He attributed this to the more arid south-west Australian conditions, causing male individuals to forage over further distances for food. His data on female *I. obesulus* was scarce due to a distinct habitat preference, hence could have accounted for their relatively small homerange in south-west Australia comparable to that in Tasmania.

Heinsohn (1966) concluded there was little overlap in homerange of *I. obesulus* and that this species was therefore strongly territorial. However Moloney (1982) observed considerable overlap for *I. obesulus*, possibly due to the human encroachment in his study sites. The homeranges of *P. gunnii* in north-west Tasmania showed extensive overlap causing Heinsohn (1966) to suggest *P. gunnii* did not defend territories. The homeranges of male *P. gunnii* were considerably larger than those of females and considerably larger than those of male *I. obesulus*. The homeranges of female *P. gunnii* were only slightly larger than female *I. obesulus* relative to that of males of the two species (Heinsohn 1966).

1.2 General Introduction

1.2.1 Distribution and Sympatry

The Southern Brown Bandicoot (*Isoodon obesulus* Shaw and Nodder) occurs widely throughout eastern Australia occupying a vast array of habitats in the dry sclerophyll forests, grasslands and heathlands of

the coastal plains east of the Great Dividing Range (Stoddart and Braithwaite 1979). An isolated subspecies in south-west Western Australia has been recorded from swampland, valley woodland, sandplain, laterite scrub, laterite woodland and *Eucalypt* meadows (McMillan 1955; Sampson 1971). Heinsohn (1966) and Moloney (1982) recorded the Tasmanian subspecies as existing in open and dense forests, recently burnt scrub, heath, open areas e.g. pastoral paddocks, grasslands and urbanised areas. More recently wetter areas of scrub sedgeland on the Tasmanian west coast were found to contain *I. obesulus* (Hocking and Guiler 1983). The four subspecies recognised and their distribution are:

I. o. obesulus, New South Wales, Victoria, South Australia
I. o. fusciventer, Western Australia
I. o. peninsulae, North Queensland
I. o. affinis, Tasmania.

However, Braithwaite (1983) is doubtful that the Tasmanian form is a valid subspecies.

In contrast, the mainland and Tasmanian forms of the Barred Bandicoot (*Perameles gunnii* Gray) are thought to be a single species. *Perameles gunnii* was once widespread across the Victorian basalt plains which originally supported perennial tussock grassland and savanna woodland with a tussock grass understorey (Seebeck 1979). It has suffered a dramatic reduction in range and the only population known to be extant is in and around the City of Hamilton (western Victoria) where the species is locally common (Seebeck 1979, 1983) though now vulnerable and threatened. In Tasmania, the Barred Bandicoot is widespread and common over parts of its range (Seebeck 1983). Heinsohn (1966) found open areas e.g. pastures were used extensively for foraging but nest sites were chosen in vegetatively dense, sheltered areas. He also recorded the animal from heath, recently burnt scrub and open forest, but these areas were utilised to a lesser degree than open habitat.

Fossil evidence suggests that although the present distribution of *I. obesulus* and *P. gunnii* do not overlap in Victoria, the two formerly occurred sympatrically there (Wakefield 1964). They co-exist extensively in sympatry in Tasmania (see Appendix A). The co-existence of the two

species provides the opportunity to examine a popular theory of community ecology. The theory postulates that no two similar species may occupy the same ecological niche and co-exist indefinitely. Furthermore, only when a resource is non-limiting may two species share identical niches and exploit that resource. This contention has been repeatedly attributed to Gause (1934), but most concisely reiterated by Hardin (1960) as "complete competitors cannot co-exist". Hardin (1960) considered Grinnell (1904) to be closer to the competitive exclusion principle and the concept became known as Grinnell's Axiom. Hence there is a limit to the similarity and therefore the number of competing species which can co-exist (Hutchinson 1959; MacArthur and Levins 1967; May and MacArthur 1972).

Brown and Wilson (1956) have hypothesised that when two partly allopatric species of comparable niche requirements become sympatric in part of their range, morphological divergence or "character displacement" eventuates. The divergences will have evolved due to interspecific competition, and survival of co-existing species will be partly subject to the ecological differences between them (Cody 1968). The most important dimensions along which species partition resources and achieve ecological separation appear to be food, space and time (Schoener 1974).

Heinsohn (1966) and Moloney (1982) in unquantified accounts concluded diet was not an important factor in ecologically separating *I. obesulus* and *P. gunnii* in the north-west and south of Tasmania respectively. Stomach contents from north-west Tasmania consisted largely of earthworms and large insect larvae (e.g. Phalaenidae, Hepialidae and Scarabaeidae) and were the main food items taken when paddocks were green and moist. During the summer months adult insects (predominantly beetles) were eaten. Blackberries and Boxthorn berries were important seasonal dietary supplements during summer months (Heinsohn 1966). In southern Tasmania the diet of both species consisted mainly of invertebrates (dipteran larvae, adult beetles, earthworms, numerous ant species, and coleopteran larvae) and some plant material (seeds, pieces of grass). Ants were the major food item which may have been associated with the drought which occurred during Moloney's (1982) study. Both investigations provided evidence of the use of olfactory senses as being important in bandicoot reconnoitering for food. However,

Moloney (1982) discovered that *P. gunnii* appeared to be unable to kill large prey (e.g. mice, rats and chickens).

Heinsohn (1966) therefore considered the use of open areas by the Barred Bandicoot, and the utilisation of vegetatively denser habitats by the Brown Bandicoot contributed considerably to reducing competition. Moloney (1982) failed to find such a clear-cut macro-habitat preference and thought ecological separation evolved from different activity periods, foraging strategies, and selection of micro-habitats.

1.2.2 Aims of the Project

The aims of the present investigation, with the purpose of acquiring a competent understanding of how the two bandicoot species are able to co-exist, are as follows:

1. Examine mechanisms by which bandicoots locate prey.
2. Discuss the differential digestibility of prey items occurring in the scats of both species of bandicoot.
3. Provide a quantified and statistically supported investigation of the diets of wild, sympatric populations of *P. gunnii* and *I. obesulus* over three seasons.
4. Determine whether the bandicoots select prey in proportion to availability (as measured by pitfall trap and soil sample analysis).
5. Define micro-habitat preferences exhibited by *P. gunnii* and *I. obesulus* where they occur in sympatry.

CHAPTER 2

TRAPPING AND CARE OF BANDICOOTS

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2.1 Trapping of Specimens

Isoodon obesulus and *Parameles gunnii* possess a wide distribution over Tasmania (Chapter 1.2.1, Appendix A). The permanent field study sites selected were three km east of Huonville along Glen Huon Road (lat. 43°01'11"S, long. 147°00'45"E). Huonville (40 km south-west of Hobart) was elected because sympatric populations of bandicoots were discovered there by Mr. P. Brown in a live-trapping study. Four Brown Bandicoots and one Barred Bandicoot were removed from two of the Huonville study sites for experiments in captivity after initially attempting to locate Brown Bandicoots in the Hobart area. Three Barred Bandicoots were also trapped and removed from a 1 ha enclosure situated behind the University while a further specimen was obtained from Mr. R. Mawbey. This animal was trapped outside of the enclosure. The vegetation in and surrounding the enclosure is of a *Eucalypt-Acacia-Casuarina* rocky woodland association with, in parts, a relatively dense grass and sedge understorey. The vegetation types situated at Huonville are depicted in Chapter 5.2, while the locations of the trapping areas are shown in Figure 2.1.1. Bandicoot trapping results for individual study sites at Huonville are presented in Chapter 6; those for the University locality in Appendix B.

The traps immediately available and employed in the present investigation were of two designs and size. The dimensions of the traps were 56 x 22.5 x 22.5 cm and 55 x 20 x 20 cm. The principal trap type was activated by the pressure of the animal's weight on a treadle secured to the trap floor. The second design required that the animal manipulate the bait attached to a hook suspended from the trap roof. Trap size did not reflect trap type used, for approximately equal numbers of the two sized traps were utilised, but only a small number of hook-type traps were operated. Both designs were structured of heavy gauge wire mesh and had locking ties falling with the door so captured specimens could not force the door open from the inside. Neither contained springs to accelerate door closure. Moloney (1982) in a similar study to the

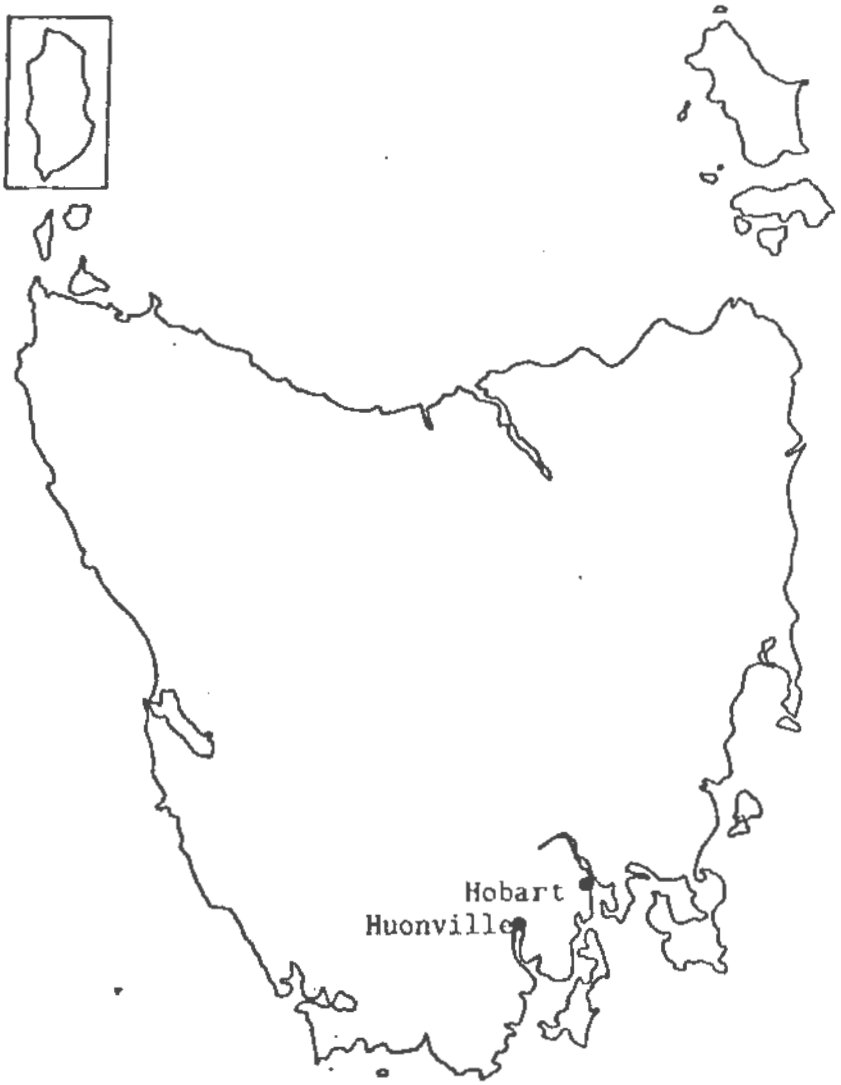


FIG. 2.1.1 Map of Tasmania and major islands showing the location of the two major trapping sites.

present discussion found the treadle design to be less efficient at capturing bandicoots by almost 50% (see Plate 3).

The bait consisted of two quarter pieces of bread with a liberal application of peanut butter and a quarter piece of apple. This was placed either on the floor to the very rear of the treadle-traps or attached to the hooks in the second trap design. Traps were placed into large, green, polythene garbage bags which served a four-fold effect:

1. Protect the animal from wind and rain.

2. Camouflage the trap from the public.

3. After initial trapping it was noted that the bags possessed a calming effect on the animal's behaviour, making handling considerably easier. This was probably related to the dimmer light entering the trap, reducing daylight disturbance to these predominantly nocturnal species.

4. To prevent scat loss (and contamination) from the traps.

In addition, traps were provided with a handful of straw for animal warmth.

Baiting usually took place between 1530 and 1800 h when traps were reset and serviced. Traps were normally examined for captures between 0630 and 1100 h. Animals were quickly transferred to a hessian sack for restraining, were weighed, sexed, examined for pouch young and general condition noted. If animals were unmarked, they were marked for subsequent recapture by clipping fur off different body parts for individual recognition. Specimens were normally released at the point of capture immediately on completion of examination except those for captive experiments which were transported to the laboratory in hessian sacks. Traps were left open during the day to detect the possible diurnal activity displayed by *I. obesulus* (Heinsohn 1966). In all, a total of 48 captures (26 males; 22 females) of Brown Bandicoots and 11 captures (4 males; 7 females) of Barred Bandicoots accounted for a total of 59 bandicoot captures.

PLATE 3 Photograph showing the principal type of trap (treadle) employed in the investigation containing a caged *P. gunnii*

Four major field trips were conducted over three seasons. The autumn sample comprised two field trips of four days duration in late March and early April, while an eight and seven day sampling programme in early June and late August-early September constituted the winter and spring samples respectively. Precise dates are presented in Table 2.1.1.

In addition to the two bandicoot species, several other species were encountered in traps. Furthermore, a large number of traps were disturbed or interfered with. Disturbed traps include those with bait present but trap sprung; bait missing, trap sprung or not sprung; bait tampered (nibbled), trap sprung or not sprung; entire trap displaced from its original position e.g. probably by Brushtail Possums (*Trichosurus vulpecula*). The relative frequency of bandicoot and non-bandicoot captures per trap night, and of disturbed traps, on each of the three Huonville study sites (Chapter 5.2) over three seasons is presented in Table 2.1.1. Two reasons possibly account for the large number of disturbed traps in winter. Firstly, an increase in rodents on the wet sclerophyll forest-pasture site and the house mouse *Mus musculus* on the wet heath-pasture site (detected by presence of faecal pellets deposited in traps only) possibly consistently activate traps without being caught. Secondly, cold winter temperatures and frosts during June probably partially cease trap closure, allowing potential captive species to escape.

On 22.17% of the 645 trap nights, a capture was sustained. The following animals and their percentage frequency of total captures accounted for this capture-success rate:

Brown Bandicoot	*Isoodon obesulus affinis*	33.57%
Brushtail Possum	*Trichosurus vulpecula*	25.18%
Long-nosed Potoroo	*Potorous tridactylus apicalis*	18.88%
Barred Bandicoot	*Perameles gunnii*	7.69%
Black Rat	*Rattus rattus*	7.69%
Brown Rat	*Rattus norvegicus*	2.80%
Eastern Native Cat	*Dasyurus viverrinus*	2.10%
Ringtail Possum	*Pseudocheirus peregrinus convolutor*	0.70%
Velvet-furred Swamp Rat	*Rattus lutreolus velutinus*	0.70%
Feral Cat	*Felis domesticus*	0.70%

TABLE 2.1.1 Table showing the number of trap nights, overall trapping success (%), the percentage number of disturbed traps (see text for explanation) and the relative frequency of the species trapped based on the number of captures per trap night, for the three seasons sampled.

Season (Field trip dates in brackets)		Wet Sclerophyll Forest-Pasture	Regenerating Wet Sclerophyll Forest-Golf Course - Fairways	Wet Heath - Pasture
AUTUMN (26th - 29th March and 10-14th April)	Number of trap nights	75	64	60
	Percentage number of trap nights containing a captive animal (overall % trapping success)	22.67%	25%	8.33%
	Percentage number of disturbed traps	6.67%	9.38%	3.33%
	No. of captures/trap night			
	Long nosed Potoroo *Potorous tridactylus apicalis*	0.08	-	-
	Brushtail Possum *Trichosurus vulpecula*	0.04	0.063	-
	Velvet-furred Swamp Rat *Rattus lutreolus velutinus*	0.01	-	-
	Eastern Native Cat *Dasyurus viverrinus*	0.01	0.016	-
	Southern Brown Bandicoot *Isoodon obesulus affinus*	0.08	0.094	0.083
	Eastern Barred Bandicoot *Perameles gunnii*	-	0.078	-
WINTER (11th - 18th June)	Number of trap nights	90	62	80
	Percentage number of trap nights containing a captive animal (overall % trapping success)	33.33%	30.65%	11.25%
	Percentage number of disturbed traps	31.11%	32.26%	31.25%
	No. of captures/trap night			
	Long Nosed Potoroo *Potoraus tridactylus apicalis*	0.11	-	-
	Brushtail Possum *Trichosurus vulpecula*	0.056	0.145	-
	Black Rat *Rattus rattus*	0.11	-	-
	Brown Rat *Rattus norvegicus*	0.033	-	-
	Ringtail Possum *Pseudocheirus peregrinus convolutor*	0.011	-	-
	Eastern Native Cat *Dasyurus viverrinus*	-	0.016	-
	Southern Brown Bandicoot *Isoodon obesulus affinis*	0.011	0.113	0.113
	Eastern Barred Bandicoot *Perameles gunnii*	0.011	0.016	-
	Feral Cat *Felis domesticus*	-	0.016	-
SPRING (26th August - 1st September)	Number of trap nights	90	64	60
	Percentage number of trap nights containing a captive animal (overall % trapping success)	32.22%	20.31%	10.00%
	Percentage number of disturbed traps	10.00%	3.13%	11.67%
	No. of captures/trap night			
	Long Nosed Potoroo *Potorous tridactylus apicalis*	0.122	-	-
	Brushtail Possum *Trichosurus vulpecula*	0.067	0.116	-
	Black Rat *Rattus rattus*	0.022	-	-
	Brown Rat *Rattus norvegicus*	0.011	-	-
	Southern Brown Bandicoot *Isoodon obesulus affinis*	0.1	-	0.1
	Eastern Barred Bandicoot *Perameles gunnii*	-	0.063	-

A large number of factors which are thought to bias trappability have been extensively documented by Kikkawa (1964), and will not be discussed here. However, some of these parameters are presented in Figure 2.1.2.

The wet sclerophyll forest-pasture study-site consistently recorded a higher species richness. The Potoroo and three rodent species were confined to this site. The wet heath-pasture site appeared to contain only *I. obesulus* and *M. musculus*. This is consistent with the observations of Newsome *et al.* (1975) and Fox (1982a) that the house mouse and Brown Bandicoots (*Isoodon* species) colonise the early seral successional stages of habitats following clearing.

The mean weights of bandicoots trapped at Huonville are presented in Table 2.1.2. Females with pouch young are included in the analysis. Pouch young were never removed from teats prior to the mother being weighed because of the considerable difficulty experienced in reattaching young, hence weights of females are considered to be an overestimate and will not be compared to those trapped at Smithton (Heinsohn 1966) and Hobart (Moloney 1982). Only initial weights of animals captured on each field trip are analysed because recaptures were observed to lose considerable amounts of weight between successive captures and because initial weights are presented by Heinsohn (1966) and Moloney (1982). Gordon (1971) has shown that weight loss between successive captures of *I. macrourus* is statistically significant. Hence trapping does appear to have a significant effect on the weight of animals captured. The two major factors responsible for this are possibly (1) the stress factor involved with being caged and (2) capture reduces the foraging time available to animals.

There appears to be a considerable difference in mean weights of males of both species in this study in comparison with those of Smithton (Heinsohn 1966) and Hobart (Moloney 1982). Rainfall was well above average in Huonville during December and January but was approximately on, or below average for the preceding months. This suggests that higher rainfall over summer may have had an extremely important effect on food availability and hence bandicoot weight in the following months. The low weights recorded by Moloney (1982) in a comparable locality in a drought year (Hobart area) support this view. Heinsohn (1966) noted

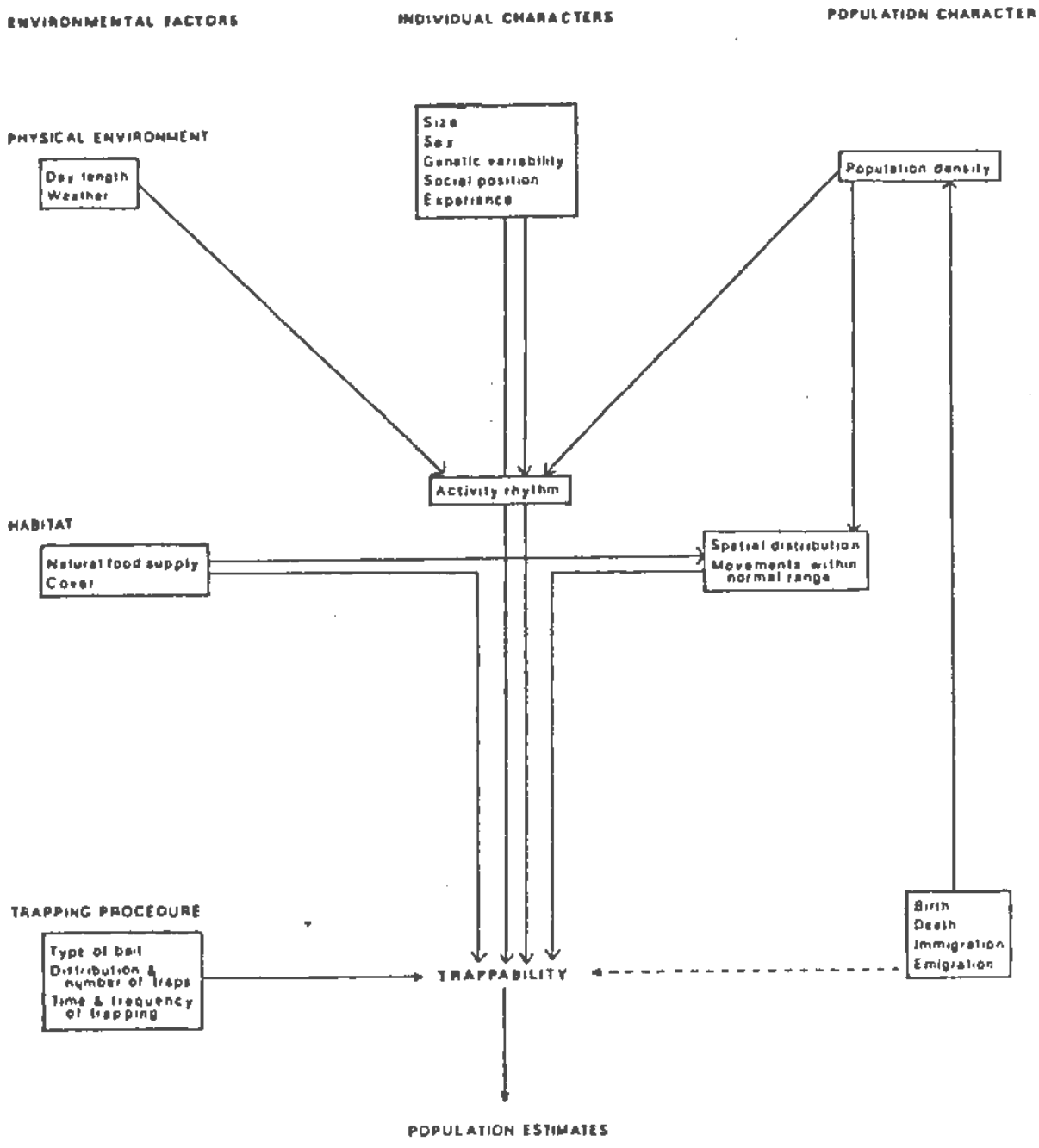


FIG. 2.1.2 Individual and population characters, and environmental factors which are likely to influence or bias a trapping programme.
(Taken from Kikkawa 1964)

Arrows indicate direction of bias.

TABLE 2.1.2 Mean weights (± standard error) in grams of male and female specimens of *I. obesulus* and *P. gunnii* from Huonville (present study), Hobart area (Moloney 1982) and Smithton (Heinsohn 1966).

	I. obesulus		*P. gunnii*	
	Males	Females	Males	Females
Huonville (Southern Tasmania)	1358.9±59.5 n = 14	731.8±84.3 n = 11	987.5±16.13 n = 4	846.4±90.9 n = 7
Hobart (Southern Tasmania)	1079.4±65.7 n = 19	716.8±46.4 n = 14	846.3±44.4 n = 8	670.0±22.3 n = 5
Smithton (North-west Tasmania)	1165.9±117.9 n = 8	946.6±73.7 n = 5	898.2±33.5 n = 26	816.5±31.9 n = 15

that *P. gunnii* rapidly lost weight in a drought year but quickly regained condition when drought-breaking rains initiated a prominent increase in food supply.

Consistent with this observation is the fact that at least one *P. gunnii* was captured with pouch young in each of the three seasons sampled. Two autumn samples revealed that one *P. gunnii* possessed a pouch young in late March. Heinsohn (1966) demonstrated that the length of the breeding season could be varied according to climatic conditions, and in seasons of abundant food supply, could extend to April but terminated in January in a drier year. The reproductive condition of *P. gunnii* is presented in Figure 2.1.3. Moloney (1982) found that both *P. gunnii* and *I. obesulus* ceased breeding in a drought year, while in western Victoria *P. gunnii* gives birth in all months of the year, but births are less frequent in some months than others. Complete cessation of breeding in the mainland population occurred during a severe drought, but heavy rains initiated births in 17 days (Lee and Cockburn 1985).

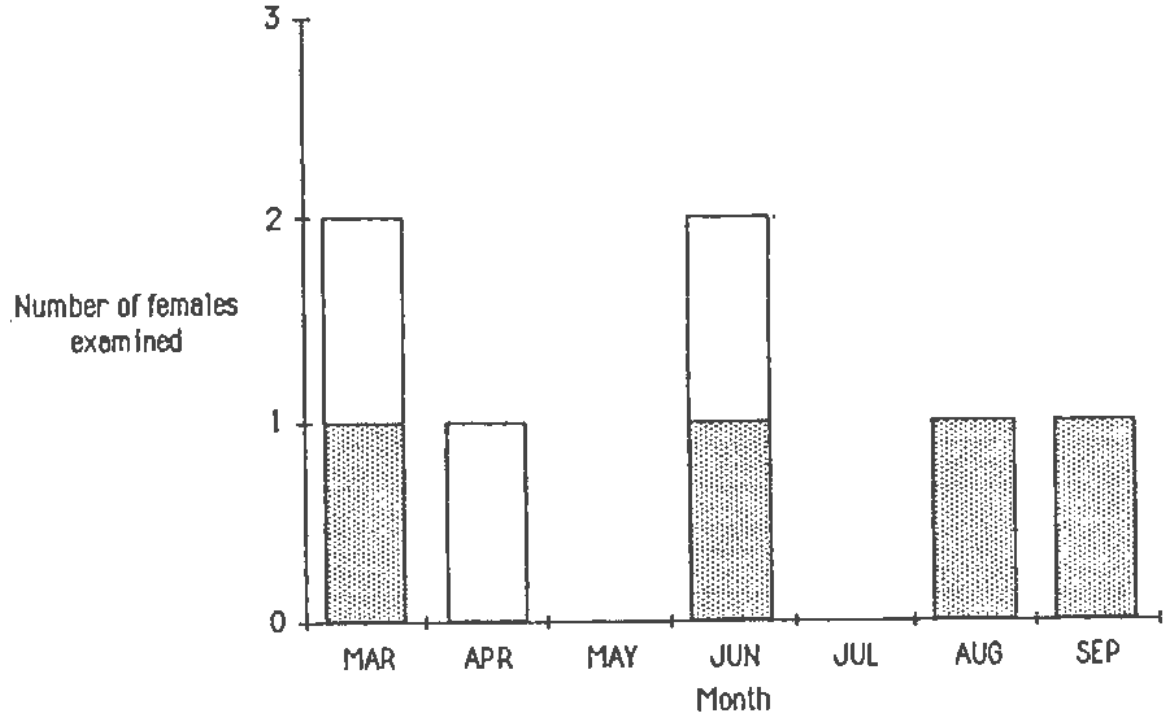


FIG. 2.1.3 Reproduction in *Perameles gunnii* in the Huonville vicinity. Open bars, total number of females examined. Stippled bars, proportion of the total number of females carrying pouch young.

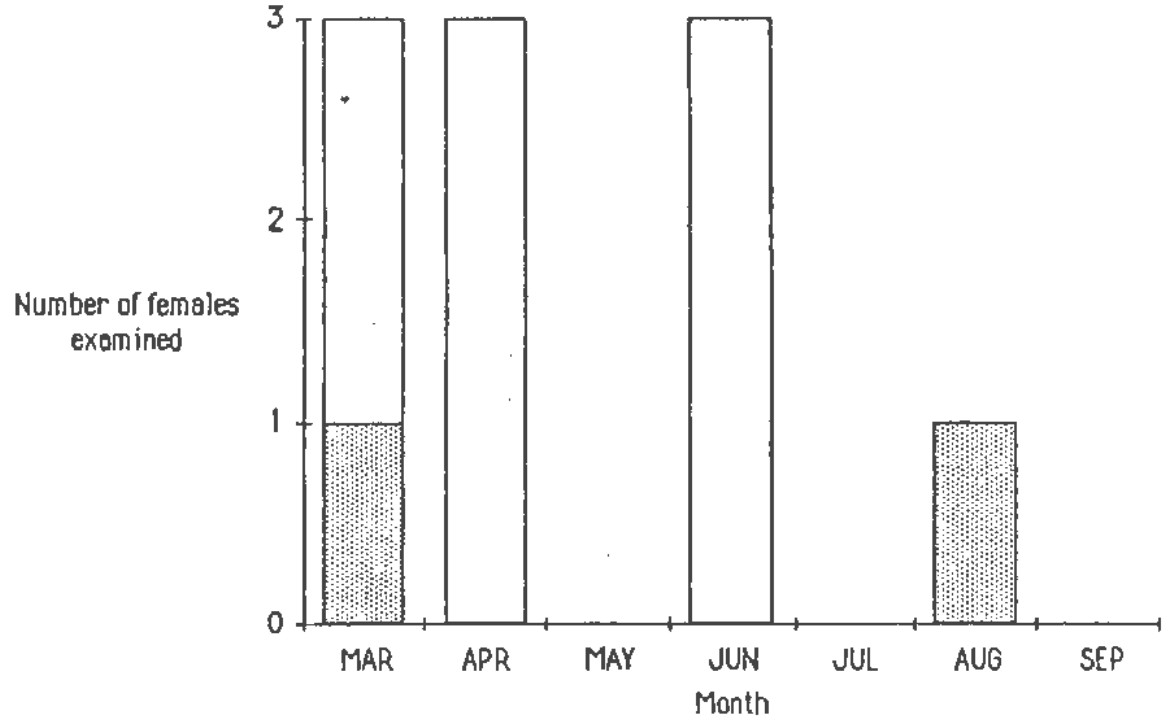


FIG. 2.1.4 Reproduction in *Isoodon obesulus* in the Huonville vicinity. Open bars, total number of females examined. Stippled bars, proportion of the total number of females carrying pouch young.

Gordon (1971) considered food supply to have some influence on breeding season of island populations of the Northern Brown Bandicoot, *Isoodon macrourus*. He observed a correlation between initiation of breeding and onset of rain on one hand and increase in weight on the other. The earliest termination of a breeding season coincided with drought conditions.

One specimen of *I. obesulus* was captured with a pouch young in late March (Fig. 2.1.4). Heinsohn (1966) observed this species to cease carrying pouch young in February, suggesting nutritional conditions were more favourable, extending breeding in this study. In eastern Victoria, *I. obesulus* possesses a definite breeding season between July and February but may breed throughout the year in western Victoria (Stoddart and Braithwaite 1979). Lobert (1985) stated that the number of litters produced per year in eastern Victoria appeared to be related to food abundance.

2.2 Maintenance of Captive Bandicoots

Nine bandicoots (five *Perameles gunnii* and four *Isoodon obesulus*) were removed from their natural habitats at various times of the year for investigations in captivity. The localities where specimens were obtained, the method of removal and transport to the laboratory is described in Chapter 2.1.

Lyne (1982) considered that development of techniques for holding bandicoots fell behind that of other marsupials, probably because early breeding attempts terminated in fighting amongst adults and mutilation of pouch young by their mothers. In view of their pugnacious behaviour (Chapter 1.1) individuals were housed separately in holding cages composed of heavy-gauge wire mesh measuring 60 x 45 x 45 cm. Subjects were held for varying lengths of time depending on when they were captured and experiments completed. Specimens subjected to extensive periods of time in captivity were placed in an outside enclosure (Chapter 3.1) for varying time intervals to alleviate the boredom possibly suffered by these marsupials in the small holding cages.

Captive bandicoots were weighed once a week (after removal from the wild) until a stable weight was obtained, and at non-determined intervals thereafter. Specimens varied in their response to captivity. Individuals either rapidly gained or rapidly lost weight. In general, Brown Bandicoots appeared to acclimate far better to the stresses imposed by captivity than Barred Bandicoots. In fact, some Brown Bandicoots became quite tame and easy to handle.

Holding cages were situated in a south-facing, semi-enclosed verandah, hence specimens experienced normal Hobart daylight lengths and temperature variations. Clean straw was placed in cages once a week for individuals to nest in. A small wooden nest-box was supplied, however not all individuals utilised these. Sliding tin trays used to collect detritus falling beneath the cages were emptied once a week.

To avoid chasing, bandicoots were trapped in the outside enclosure when being removed to their holding cages. The method of trapping employed was identical to that described in the previous section, and this presumably eliminated possible exhaustion and subsequent deaths (Seebeck 1979). Hessian sacks were employed to transport animals between the enclosure, holding cages and laboratory.

In view of the bandicoots' diverse, natural food selection, the captive diet consisted of a varied array of foods. The diet was a modification of that suggested by Lyne (1971, 1982) and Seebeck (1979) and as advised by Mr. R. Mawbey. Both species were maintained on 'Pal meaty bites', macropod pellets, brown bread and peanut butter, mixed budgie seed, sliced carrots, apples and lettuce and blackberries when in season. In addition earthworms, mealworms and cockroaches were added when available. Minced meat was not supplied because of the expense involved. 'Pentavite' childrens multivitamin drops were added to the diet once a week. Food and water were supplied *ad libitum* in plastic containers three times a week on weekdays so enough food remained between feeds.

Despite attempts to accommodate the bandicoots as comfortably as possible, four specimens (three *P. gunnii* and one *I. obesulus*) died during the course of the study. Two of these were examined for autopsy

by Dr. D. Obendorf situated at Mt. Pleasant Laboratories in Launceston (northern Tasmania). Both specimens displayed severe stress syndromes and the author suspects that stress was responsible for the deaths of the additional two specimens. Mackerras and Smith (1960), Stodart (1966) and Seebeck (1979) suggest that successful maintenance of captive bandicoots appears to require reasonably sized outdoor enclosures with a good ground cover. However, Lyne (1971, 1982) was able to maintain bandicoots in smaller indoor cages. The author suggests that the holding cages used in the present investigation were too small to maintain bandicoots comfortably.

On completion of investigation, subjects were released at the point of capture because Gordon (1971) has shown there is a high probability that bandicoots (*Isoodon macrourus*) entering a foreign habitat will leave anyway. Furthermore, animals released into a familiar habitat showed greater survival than those released in an unfamiliar habitat and this was probably associated with their lack of familiarity with the area.

CHAPTER 3

PREY DETECTION TRIALS

CHAPTER 3

PREY DETECTION TRIALS

3.1 Olfactory and Auditory Trials

3.1.1 Introduction

A fundamental component of the ecological niche is the food available to a species. Implicit in this element are the techniques employed by species in locating and exploiting food, and in distinguishing their favoured species from less desirable prey. Hence, strategies utilised in seeking food are important in structuring ecological communities (Stoddart 1980).

Olfaction, the mechanism of odour perception, plays a dominant role in the feeding and foraging behaviour of nocturnal species (Stoddart 1980). Although it is generally accepted that bandicoots locate prey via their olfactory senses (Stodart 1977), only Heinsohn (1966) and Moloney (1982) provide evidence supporting this view. The continual sniffing motions, nasal-ground contacts and lateral movements of the snout are obvious features to anyone who has ever watched a foraging bandicoot. A study by Kratzing (1985) examined the olfactory sense organs in the early pouch young and adult *Isoodon macrourus*.

The evidence presented by Heinsohn (1966) and Moloney (1982) was based on mice placed out of the bandicoots' viewing range. The author considers that *Perameles gunnii* and *Isoodon obesulus* would not regularly be able to capture mice in natural situations. Furthermore, it would be highly desirable for a species which procures food partially from the soil and partially from the surface to obtain an odourous stimulus from a potential prey item buried in soil, than to randomly dig in hope of eventually discovering food. There is evidence to suggest that bandicoots mark areas of potential food sources in a similar way to patterns of scent marking in mammalian territorial behaviour (MacDonald 1980). Bandicoots often defaecate in their feeding dishes as though marking previously encountered food areas (Moloney 1982; present investigation). Consistent with this view is the fact that scats were occasionally found

in the field adjacent to, or on top of the characteristic conical pits excavated by bandicoots.

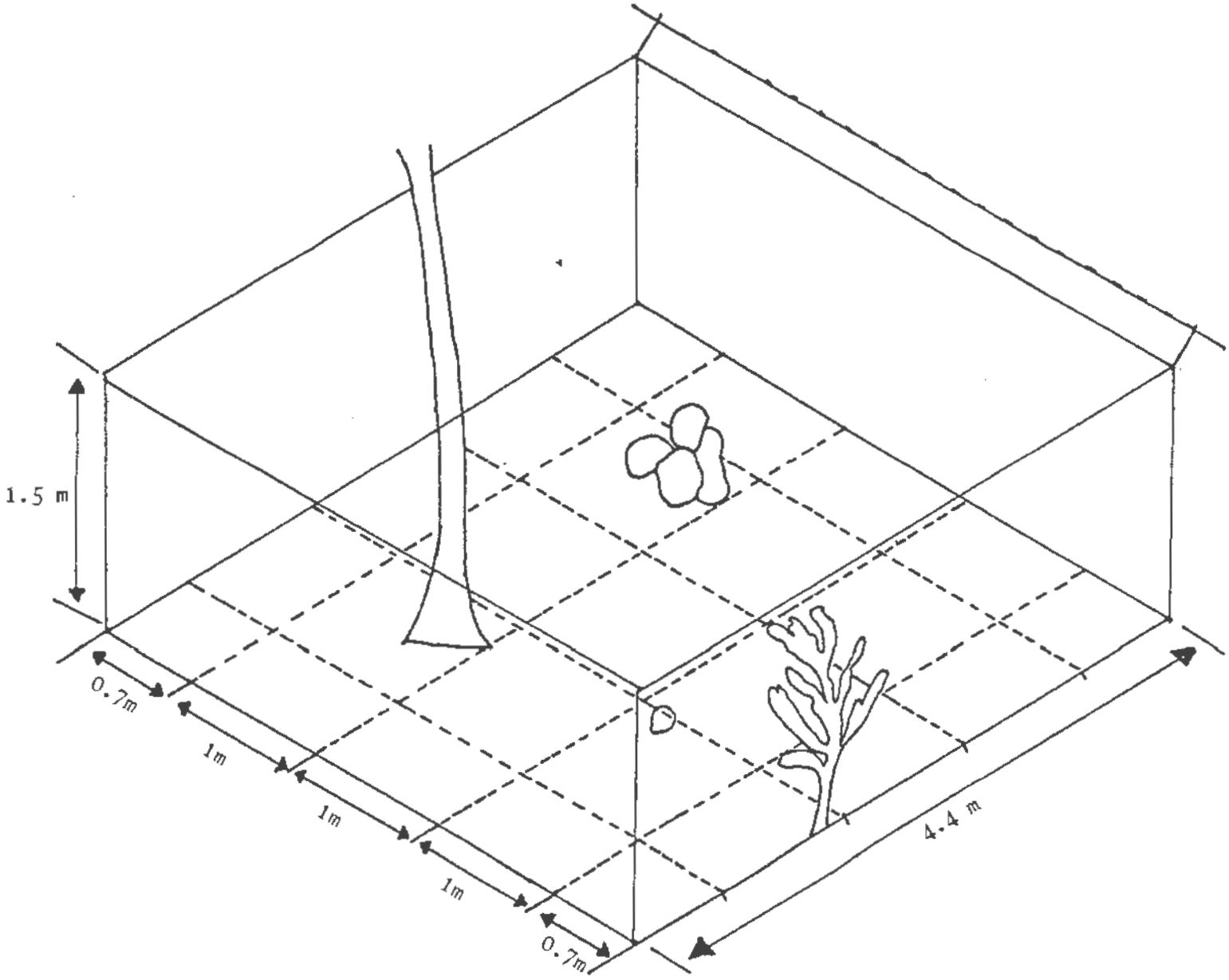
It is not known whether bandicoots utilise auditory or visual senses in prey detection. The aims of this section are therefore to examine the olfactory senses of *P. gunnii* and *I. obesulus*, utilising prey which bandicoots are known to, or likely to consume in natural situations. Furthermore the importance of hearing to the bandicoots will be investigated by artificially mimicking insect movements.

3.1.2 Materials and Methods

Investigations into prey location by *Perameles gunnii* and *Isoodon obesulus* were executed in an outdoor enclosure within a larger compound situated behind the Zoology Department of the University of Tasmania. A diagram of the enclosure is presented in Figure 3.1.2.1. The dimensions of the enclosure measured 4.4 x 4.4 x 1.5 m. Two centimetre wire mesh completely enclosed and roofed in the area, attached to steel posts in the ground, and to steel piping providing the roof framework. The wire mesh walls of the enclosure were set in the ground and embedded in concrete with chicken wire (used to reinforce the larger mesh). Hessian strips were attached to the enclosure wall adjoining the adjacent enclosure to eliminate visual contact with Eastern Native Cats (*Dasyurus viverrinus*) housed within. However, this never prevented visual contact from specimens outside of the two enclosures.

The enclosure is situated on a slope hence after heavy rain, straw and woodchips dispersed on the floor often accumulated at the bottom end of the enclosure. Vegetation in the enclosure consisted of a small shrub *Beyeria viscosa* and one tree (*Acacia mollissima*) which projected through the roof. Nest boxes were supplied, however, most specimens utilised the straw and built nests beneath logs. Food and water were supplied *ad libitum*, hence it was hoped diet had no effect on the trials in any way. The diet provided was as described in Chapter 2.2.

FIG. 3.1.2.1 Diagrammatic representation of the enclosure used in prey detection trials. Intersections of the interrupted lines represent the reference points. (Modified from Moloney 1982)



A four by four grid system was marked out in the enclosure dividing the area into 16 reference points (see Fig. 3.1.2.1). Points were situated at 1 m intervals resulting in a 0.7 m periphery surrounding the entire reference area, and were marked with red ribbons tied to the enclosure walls (reference points where two ribbons intersected). The points were denoted two numbers depending on the row and column each one resided in.

At each point was placed either a cup containing ground prey extract or non-extract. Cups were simply small, plastic bottle tops 15 mm high and 27 mm in diameter containing 20 drops of either solution. Ground prey extract consisted of 7.5 g of freshly killed earthworm or cockroach ground in 50 ml of water using a mortar and pestle, while non-extract (initially the cup only) comprised 20 drops of water. Water appeared to have no different effect on the bandicoots than the empty cups. Four trials at each of four depths (2.0, 2.5, 3.0 and 3.5 cm) were tested on three *I. obesulus* and three *P. gunnii*. Hence, a total of 16 trials were undertaken for comparative purposes on each species, separately using cockroach and earthworm. A random numbers table was used to decide which point received a scented (extract) or non-scented cup. The numbers were always altered so as not to place cups in the same pattern on two consecutive days. A piece of woodchip was placed over each cup to prevent filling it with dirt. The excavation containing the cup was then filled in with dirt and flattened using a hand trowel, and the entire floor surface covered with straw to eliminate any visual cue which the bandicoots may have perceived from a fresh digging.

Setting the cups usually took place between 1500 and 1700 h and individual bandicoots were tested one at a time after at least two days acclimatization to enclosure conditions. Reference points were examined between 0700 and 0900 h and a digging or conical pit (nose probing) within a 5 cm radius of the cup was considered as an odorous stimulus detected by the bandicoot, hence was recognised as a discovery. Usually, following detection, the cup was moved a few centimetres within the reference point for the preceding trial to prevent the possibility of animals learning to find where cups were buried.

Cups were raised out of the ground and washed thoroughly in hot water. Detergent was never employed because of the odour it would have transmitted to the cups. Paper towels were used to dry the cups which were occasionally left to stand in open air to enhance removal of any odour possibly remaining on the tops. The procedure was repeated until the total number of trials was completed. Olfactory trials were occasionally suspended and auditory trials initiated to prevent continuous removal and replacing of individuals in the enclosure and therefore subjecting specimens to continual stress.

For the auditory trials, only six reference points were employed and for practical purposes these were closest to the enclosure door. The sounds emitted by a cockroach "fluttering" in wood shavings within a plastic container were recorded onto an endless reel cassette. This presumably simulated the sound produced by an insect moving within soil particles. The cassette was continually run and the sound played through three speakers (49 mm diameter) all night until the mechanism was switched off the following morning. Two speakers were attached (soldered) to approximately 12.5 feet of lead each, the third being in contact with approximately 25 feet of lead so the cassette recorder could be housed in an observation hut outside of the enclosure. The leads were run into the enclosure and the three speakers were buried at the same depth each trial; depth and volume were altered between trials in an attempt to revelate the greatest depth and lowest sound volume at which each species could locate the speakers.

Speakers were placed into plastic bags before burying to prevent rain water seeping into, and damaging them. Dummy (control) speakers were, for economic reasons, plastic vial tops of similar diameter to the speakers, wrapped in plastic bags and were buried at the same depth to the speakers. As the leads had to be buried, a false trail was dug leading to the dummy speakers. At no time did the bandicoots ever appear to locate the lead and follow it to the speaker. As for the olfactory trials, a digging within a 5 cm radius of the speaker was regarded as a finding by the bandicoot. Initially only two speakers (and therefore two dummy speakers) were available and employed on the first three Barred Bandicoot trials. Three speakers and dummy speakers were used in all trials thereafter. The speakers were generally set up between 1700

and 1800 h and examined the following morning between 0730 and 0900 h. Once a speaker or dummy speaker was found, it was dug up and moved a few centimetres within the reference point. The remaining speakers and non-speakers were also raised out of the soil and buried again. Occasionally speakers were moved between reference points, but as this involved considerable digging which may have stimulated the bandicoots into excessive digging i.e. the smell of fresh soil, movement was kept to a minimum. As for the olfactory trials the entire floor surface was covered with straw, preventing visual contact with spots of burial. A total of 20 trials were carried out on two specimens each of *P. gunnii* and *I. obesulus*.

In conjunction with examining the reference points for olfactory and auditory trials, the bandicoot diggings were filled in and their total number recorded each morning. The number of diggings were analysed for temperature effects, since it was thought that excavations decreased in colder months and increased in warmer months. Thus, it was anticipated that the number of excavations may be a good indication of activity.

3.1.3 Results

Both *Perameles gunnii* and *Isoodon obesulus* were capable of locating extract and non-extract cups in both sets of trials using cockroach and earthworm extracts. The proportion of scented to non-scented cups discovered by *P. gunnii* is presented in Table 3.1.3.1 and for *I. obesulus* in Table 3.1.3.2.

TABLE 3.1.3.1 Chi-square values comparing proportion of scented and non-scented cups located by three *P. gunnii* (total number of trials in brackets).

Extract	Number of Scented Found	Number of Non-scented Found	D.F.	X_1^2	(Yates Correction)
Earthworm (16)	15	4	1	6.42	$0.01<P<0.025^{*}$
Cockroach (16)	26	9	1	8.29	$0.001<P<0.005^{*}$

* denotes a significant difference

TABLE 3.1.3.2 Chi-square values comparing proportion of scented and non-scented cups located by three *I. obesulus* (total number of trials in brackets).

Extract	Number of Scented Found	Number of Non-scented Found	D.F.	X^2_1	(Yates Correction)
Earthworm (16)	11	7	1	0.94	$0.25<P<0.5$
Cockroach (16)	31	14	1	6.44	$0.01<P<0.025$*

* denotes a significant difference

The proportion of scented to non-scented cups located by *P. gunnii* is significantly greater for earthworm ($X^2 = 6.42$, d.f. = 1, $0.01<P<0.025$) and for cockroach ($X^2 = 8.29$, d.f. = 1, $0.001<P<0.005$). For *I. obesulus* the difference is significantly greater for cockroach ($X^2 = 6.44$, d.f. = 1, $0.01<P<0.025$) but not significant for earthworm ($X^2 = 0.94$, d.f. = 1, $0.25<P<0.5$).

Four-fold (two by two) contingency chi-square tables illustrated that the proportion of scented cups found by both of the Peramelid species is not significantly different for earthworm and cockroach (*P. gunnii*, $X^2 = 0.30$, d.f. = 1, $0.5<P<0.75$; *I. obesulus*, $X^2 = 0.40$, d.f. = 1, $0.5<P<0.75$).

The number of speakers and non-speakers located by *P. gunnii* and *I. obesulus* is shown in Table 3.1.3.3. Two specimens of *I. obesulus* failed to detect any speakers or non-speakers, hence could not statistically be tested. One of the two specimens of *P. gunnii* located both speakers and non-speakers quite readily. Although there is a trend, the number of speakers discovered is not significantly greater than the number of non-speakers ($X^2 = 2.63$, d.f. = 1, $0.1<P<0.25$).

Perameles gunnii was able to detect both extracts to 3.5 cm and the speakers to 5 cm, whereas *I. obesulus* located cockroach extract to 3.5 cm but earthworm to only 3.0 cm. No pattern emerged between depth of extract buried and number of findings, suggesting that the olfactory

TABLE 3.1.3.3 Chi-square values comparing the proportion of speakers and non-speakers found by *P. gunnii* and *I. obesulus* (number of trials in brackets).

Species	Number of Speakers Found	Number of Non-speakers Found	D.F.	X^2	(Yates Correction)
Perameles gunnii (20)	13	6	1	2.63	0.1<P<0.25
Isoodon obesulus (20)	-	-	-	-	-

mechanisms appeared to function equally as well at the four depths tested for both species (excluding the fact that *I. obesulus* did not locate earthworm extract at 3.5 cm).

The mean number of diggings per night for *P. gunnii* was 61.17±4.33(S.E.) over 47 observations, and for *I. obesulus* 9.01±1.20 for 51 observations. However, as the correlation coefficient for both species relating number of diggings to mean, minimum temperature is not significant (*P. gunnii*, r = -0.215, d.f. = 45, 0.1<P<0.2; *I. obesulus*, r = +0.192, d.f.=49, 0.1<P<0.2), the author is reluctant to test this fact any further as at no stage was an individual of either species present in an enclosure simultaneously.

3.1.4 Discussion

The findings of the present investigation are consistent with the generally accepted view that bandicoots locate prey via their olfactory senses (Heinsohn 1966; Stodart 1977; Moloney 1982). The results also reveal that not solely whole, live prey is required, but a ground extract is sufficient to be detected. Furthermore, cockroaches which appear more odorous than earthworms to human perception appear to be more odorous to both bandicoot species as indicated by the significance level of the chi-square test. However, when statistically tested together, the proportion of scented cups located by *Perameles gunnii* and *Isoodon obesulus* is not significantly different for cockroach or earthworm.

The difference between the number of earthworm-scented to non-scented cups located by *I. obesulus* was not significant which may indicate this item to be of less importance in the natural diet of *I. obesulus* than *P. gunnii*. This could not be demonstrated in the present study (Chapters 4 and 7). Burghardt (1967) has shown that the response of naive, inexperienced individuals of two snake species, *Thamnophis radix* and *Opheodrys vernalis*, as measured by the rate of tongue flicking, to odours of various prey extracts are quite different, and coincide with what is known of the feeding ecology of these snakes in the wild. However, Heinsohn (1966) found earthworms to be a major component in the diet of both *P. gunnii* and *I. obesulus* in north-west Tasmania. Hence, I suggest the finding in the present study possibly relates to variation between a small number of individuals, and further trials may depict a significant difference. For instance, one *I. obesulus* used in olfactory trials rejected earthworms when presented with them, hence may have found earthworms unpalatable and ignored the scented cups despite detecting an odorous cue.

The detection of non-scented cups may have arisen from the following sources:

1. The bandicoots located the cups randomly while foraging for prey in the enclosure.

2. The bandicoots obtained olfactory cues from the freshly eroded soil.

3. Odorous cues could have remained on cups employed in one trial as an extract cup and washed thoroughly but used in the following trial as a non-extract cup.

4. Extract was spilt into the digging containing the cup and in the following test a non-extract cup was located via the odorous soil.

5. Natural prey resided into the digging containing the cup and bandicoots located the non-scented cup via the prey.

Of the above explanations, (4) and (5) appear to have little effect. The investigator was extremely careful not to spill extract into reference point areas, and if bandicoots tipped cups over (during investigations) the cup was shifted a few centimetres within that reference point for the subsequent trial. Although flatworms occasionally resided into cup holes, over the entire study this occurred very infrequently. For the Brown Bandicoot, the mean number of diggings per night is extremely low, despite the number of findings still being relatively high. At least in *I. obesulus*, random digging appeared to be minimal over the entire study. The maximum number of diggings recorded by *I. obesulus* was 32. This reduces the effect of (1). The maximum number of diggings recorded by *P. gunnii* was 123. Therefore, at least over the duration of parts of the study, *P. gunnii* possibly located some non-extract cups while seeking prey in the enclosure.

Three dummy trials were performed on the Barred Bandicoots by placing at the 16 reference points 16 empty cups. Five of the cups were discovered in the three trials, coinciding with considerable digging activity. This supports the view that *P. gunnii* may have randomly located some non-extract cups.

Explanation numbers (2) and (3) are possibly the greatest source of detected, non-scented cups. Although the cups were thoroughly washed until no odour was apparent, if the bandicoots' olfactory senses are capable of superior perception to that of human olfactory senses, it is quite possible bandicoots were able to detect the odour remaining on the cup. An alternative view is that the cups themselves possessed an odour. However, as a larger number of non-scented cups were not discovered, and the cups used were definitely not new, it is unlikely this factor played a major role.

The most likely explanation for the non-scented cups is that the bandicoots were possibly perceiving odorous cues emitted by freshly disturbed earth. Ashton and Eayrs (1970) have demonstrated that dogs' ability to locate buried objects of varied forms decreases considerably as the age of the burial increases. As cups were dug up and buried daily in the present investigation it is highly probable that the bandicoots were responding to freshly disturbed earth. Similarly, a proportion

of the extract cups may have been located via the same cue. However, the extracts were probably providing the additional stimuli resulting in the significant differences recorded for three of the four sets of trials.

Two further factors inherent in the present investigation as noted by Ashton and Eayrs (1970) were, firstly, that cups were probably less likely to be located when the overlying soil was tightly packed, and secondly, that the odour is likely to be dispersed quicker if air is in motion surrounding the object emanating the odour. Hence, on windy nights the bandicoots were possibly less likely of encountering a cup, and less likely to locate a cup if the filtering mechanisms of the soil was impeded by increasing soil impermeability to odour. Thirdly, the human odour transmitted to the cups while handling may have had some effect on their detection by the bandicoots.

The slight trend apparent in the auditory trials may indicate that hearing is more important in the Barred Bandicoot. However, only one of the two *P. gunnii* specimens appeared to possess any ability at locating either speakers or dummy speakers. This specimen may have been responding to either the odours emanating from a fresh digging as described previously, or emitted by the plastic bags employed to protect the speakers. Once in the locality of a speaker, sound may have been providing the additional stimulus resulting in a tendency for a greater number of speakers to be detected than non-speakers. The aroma from the plastic bags probably deteriorated after a period of time being buried. This was tested unsuccessfully on the subsequent specimen of *P. gunnii* by providing speakers and dummy speakers with new plastic bags.

The auditory trials possibly represent individual variation in responses to speakers and non-speakers. A larger number of tests should be conducted on a larger number of specimens of both species. However, this was not practical within the limits of the present investigation. Furthermore, an investigation into the location of frogs by the Brown Bandicoot revealed that acoustic stimuli (frog mating calls) was not important in locating frogs (M. Heel, personal communication 1985). This is consistent with the observations in the present investigation that hearing appears to be unimportant in the Brown Bandicoot.

The present study did not examine the detection of vegetable matter e.g. seed, fungi by the bandicoots. This could be tested by placing an equal weight of seeds into the cups and following the methods described in the present investigation. The detection of hypogean fungi by dogs and other vertebrates e.g. the bettong, *Bettongia lesueur*, almost certainly depends on olfaction (Stoddart 1980). Bandicoots consumed considerable quantities of underground fungi in the present investigation (Chapter 7). This could be tested by burying fungi in a similar manner to that described previously and recording the number of fungal findings as against findings of non-fungal (control) diggings. Similarly the seeds or fungus could be ground into an extract and placed in cups as described previously.

The possible marking of previously encountered food areas is of interest to the olfactory biologist for scats deployed by mammals have been recognised to mark territories, trails, middens, feeding sites, amongst other functions (MacDonald 1980). Furthermore, scats may be coated with anal gland secretions (MacDonald 1980; Stoddart 1980). The factors stimulating a bandicoot to deposit scats next to a digging warrants further investigation for it is possible bandicoot token marking may serve more than one function e.g. territorial and food locating.

Moloney (1982) also demonstrated that *P. gunnii* expended more time digging when enclosed than *I. obesulus*. Unfortunately, the application of the results with respect to prey detection trials apply to enclosed animals in southern Tasmania and their application to wild animals in other parts of the state must be treated with caution. However, the possibility that *P. gunnii* may spend more time excavating than *I. obesulus* cannot be overlooked. If this view is valid, a difference in diet may possibly arise. Very little difference in diet was observed (Chapter 7), although earthworms, a prey item which would possibly be taken from the soil could not be detected in scats. The use of radio-telemetry could possibly detect the proportion of time spent digging in the wild by *I. obesulus* and *P. gunnii*, hence whether one of the species feeds more from the soil surface. However, the greater occupancy of denser habitats by the Brown Bandicoot may render observation difficult. *Isoodon obesulus* may be simply more effective at locating prey in the soil

and therefore it is not necessary to spend as much time digging. However, Heinsohn (1966) considered *I. obesulus* to be a more active digger in the wild and considered the relatively stouter body to be an adaptation for excavating.

CHAPTER 4

METHODS OF EXAMINING WILDLIFE DIET

CHAPTER 4

METHODS OF EXAMINING WILDLIFE DIET

4.1 Methods

Various techniques have been derived for analysing wildlife diet. The methods involved can be divided into three broad categories: direct observation, examination of stomach contents, and faecal or scat analysis. The technique applied to different species generally takes into consideration a factor inherent with either the way the animal collects its food or digests it, as will briefly be discussed.

Direct Observation

Directly observing foraging animals is time-consuming and limited by the field of range between the observer and the animal in question. Furthermore the behaviour of cryptic, particularly nocturnal species, and their response to the observer may render observation impossible. Selection of dense, vegetated habitats make viewing extremely difficult. Heinsohn (1966) provided some direct observations on feeding by *Perameles gunnii* and *Isoodon obesulus*, however these were restricted to larger prey items e.g. earthworms which were easier to observe than small prey e.g. beetles.

At best, direct observations should possibly be utilised in conjunction with additional dietary techniques. Smith (1982) successfully combined direct observations with scat analysis on the arboreal Sugar Glider, *Petaurus breviceps*, to obtain seasonal changes in gliders' feeding time undertaking a particular foraging strategy, while assessing insects consumed. Ford *et al.* (1982) consider direct observation to be of considerable importance in attaining the diet of certain bird species.

Examination of Stomach Contents

Analysis of stomach contents has the obvious disadvantage in that it involves animal sacrifice and hence reduction of their population size, unless a flushing technique is employed and then animal destruction

is not necessary. Stomach flushing has been employed successfully on birds, lizards, frogs, turtles and crocodiles (Ford *et al.* 1982), while recently, stomach suction has been utilised to examine the food consumption of the koala, *Phascolarctos cinereus* (Nagy and Martin 1985).

As a means of ascertaining diet, stomach contents have the advantage that dietary items are likely to be less digested and fragmented than those occurring in faeces. Heinsohn (1966) considered that analysis of stomach contents of *P. gunnii* and *I. obesulus* was biased towards earthworms and subterranean insect larvae because these appeared to be more resilient to digestion than adult insects. Hall (1980b) examined the diet of two sympatric species of *Antechinus* using stomach contents and scat analysis and postulated that soft-bodied prey e.g. earthworms are possibly totally digested, hence overlooked in faeces, although were readily detected in stomachs.

Faecal or Scat Analysis

In contrast to stomach examination, attaining diet by faecal analysis does not involve sacrifice of predators (Hall 1980b; O'Neill 1984). However results obtained can only give an approximate indication of the diet since differential digestibility of food items will result in absolute proportion in faeces differing considerably from the proportion of food items actually ingested (Putman 1984). Whereas, in some cases, relatively undigested food items from stomachs can be quantified, the same is not applicable to scats (Calver and Wooller 1982). An added advantage lies in the fact that in particular for larger herbivores, depositing large, conspicuous scats, visual contact or handling of the animal need not be achieved for scat collection.

4.2 Digestibility Trials

4.2.1 Introduction

A confusion in the analysis of scat is the differential digestibility of food items (Putman 1984). Hence estimation of the abundance of various food items can only be approximations to the natural diet (Adams *et al.* 1962). It is sometimes assumed that all plant species

eaten by herbivores can be detected and that leaf cuticle areas of each plant species appear in faeces in proportion to that ingested. The assumption is valid only if the leaf epidermis is proven to be unaffected by digestion (Storr 1961; Dunnet *et al.* 1973). The problem is magnified further for omnivores considering that invertebrate matter may be less resistant to digestion than plant matter. It has been suggested (Hansson 1970; Putman 1984) that the quantity of food item appearing in faeces can be calibrated to the amount ingested resulting in a conversion ratio or correction factor similar to that as applied by Lockie (1959).

The correction factor can be established in captive feeding trials and then related to free living animals. Conversion ratios have been established for the Fox, *Vulpes vulpes* (Lockie 1959), the Quokka, *Setonix brachyurus* (Storr 1961), the Snowshoe Hare, *Lepus americanus hairdii* (Adams *et al.* 1962) and the Brushtail Possum, *Trichosurus vulpecula* (Dunnett *et al.* 1973).

Both *Perameles gunnii* and *Isoodon obesulus* are known to consume earthworms, at least in north-west Tasmania. Brockie (1959) found the only indicator of earthworms in the diet of the Hedgehog (*Erinaceus europaeus*) in New Zealand was the presence of chaetae in the faeces. Bradbury (1977) considered that earthworms undergo almost complete digestion in the Badger (*Meles meles*) diet and are difficult to detect in scats. However, he demonstrated that earthworm gizzards and chaetae could be recovered from scats. Kruuk and Parish (1981) have shown that the number of gizzards and a score for the number of chaetae present were closely correlated in badger scats. Furthermore, Bradbury (1977) has recovered earthworm gizzards from the fox and hedgehog in England.

A study was undertaken to examine the faecal pellets of bandicoots presented with earthworms for chaetae and/or gizzards. Finally, assuming either gizzards or chaetae are recovered, to establish correction factors for these soft-bodied prey. In addition, an attempt to establish a correction factor for adult insect will be made using a representative insect as the prey.

4.2.2 Materials and Methods

Bandicoot feeding trials were conducted indoors in the Zoology Department's animal house, a constant temperature room at 20°C. Holding cages were not utilised in digestibility trials because scats were usually lost to the straw provided for nesting, and cages could not be thoroughly searched without removing animals (and hence subjecting specimens to additional stress). Instead bandicoots were accommodated in a double bird aviary which allowed thorough checking for scats without having to remove animals. The room was fitted with an automatic timing device allowing near to 12 h of light and dark between approximately 1900 and 0700 h.

The dimensions of the aviary measured 2.35 m high, 1.76 m wide (hence each half was 0.88 m wide), and 0.72 m from front to back. The aviary had been built into the wall, therefore three walls of the aviary were fenced in by one of the room's walls. The front consisted of 13 mm light-weight wire mesh held firm by wooden panelling. Both halves of the aviary possessed a door (1.04 m high, 0.46 m wide) consisting of wire mesh and wood panelling. The top half of the aviaries are separated by masonite, the lower half by wire mesh. Hence to prevent visual contact between specimens in the aviaries a cement sheet partition was placed between the aviaries. This did not prevent olfactory contact between specimens in either aviary. The aviary floors comprised a sliding tin tray under both halves, which could be removed and cleaned as required.

Bandicoots were supplied with straw for nesting and a nest box consisting of a rectangular plastic dish measuring 38.0 x 24.5 x 15.5 cm, inverted with one end removed allowing bandicoots to enter and shelter beneath. Water was constantly supplied *ad libitum* in small plastic dishes while test food was supplied in rectangular plastic containers (18.0 x 2.5 x 6.5 cm). Since bandicoots were often observed to deploy scats in feed dishes, rectangular pieces of plastic garbage bags were placed beneath feed and water dishes to aid in scat collection and spillage of test food. This partially prevented scat contamination; however, bandicoots did not solely deposit scats in feed dishes. Hessian strips were strung over the lower half of the aviary to prevent visual

disturbance of bandicoots by visual contact with humans in the animal house.

The selection of food items employed in digestibility trials has been discussed in the previous section. Earthworms were obtained from the compound situated behind the Zoology Department. The American Cockroach, *Periplanata americana* was selected as the representative insect because a constant supply was cultured in the Department.

Bandicoots were presented with a known weight of test food; freshly killed cockroach and/or earthworms. Cockroaches were sacrificed by first anaesthetizing with CO_2 and then beheading. Earthworms were lightly anaesthetized only to prevent drying out. Food was presented between 1700 and 1800 h and examined the following morning between 0800 and 0900 h, and the proportion remaining in feed dishes weighed and subtracted from the weight supplied. Animals were provided with solely test food for three days, and thereafter, returned to the normal diet. Scats were collected from the aviary during and after the three day period until they were clear of test food, and preserved in 70% alcohol in plastic vials, pooling faeces for each test.

Scats were analysed in an identical manner to the way in which scats from the field were dissected (Chapter 7.1.2). The method was a modification of that applied by Kruuk and Parish (1981). Portions of the scat were teased apart in 70% alcohol using fine forceps under a dissector microscope and any identifiable structures removed and placed in 70% alcohol. The remaining contents of the petri dish were emptied into a sieve system containing a 500 µ sieve over a 355 µ sieve. Running water was employed to screen the large proportion of dirt in the scats which made observation difficult. Water and particles falling through the sieves were collected in containers measuring 165 x 165 x 100 mm. The contents of the 500 µ sieve were washed into a petri dish and further examined for identifiable structures. Portions of the scat were taken, teased apart and sieved until the entire faecal pellet was analysed. The portion remaining in the 355 µ sieve after all sievings was examined separately. A wide-bore pipette was employed to draw a 1.5 ml sample from the solid material which had settled at the bottom of each container. These subsamples were washed into a petri dish and

stained with picric acid for 10 minutes and examined microscopically.

The number of positively identified structures which could be used to quantify prey numbers appearing in faeces was recorded for each trial. Structures sought for were: for earthworms, gizzard rings and chaetae; for cockroaches, wings, mandibles, antennae and legs. Individual bandicoots were weighed before and after feeding trials, and allowed two days acclimatization to the aviary conditions. All except one trial were conducted on two individuals at a time using both aviary halves.

4.2.3 Results

A small number of trials were only practical within the limits of the present investigation. Two trials involving earthworm only, performed on two specimens of *P. gunnii*, failed to reveal any structures resembling earthworm. Similarly, two trials each combining earthworm and cockroach on two specimens of *I. obesulus* failed to detect chaetae or gizzard rings. One test involving solely cockroach on one specimen of *P. gunnii* did not disclose any identifiable structures. A total of six trials in which cockroach was provided to two Brown Bandicoots (with or without earthworm) liberated a small number of identifiable structures. Predominantly femurs and tibias emerged, although mandibles were also detected. The results of digestibility trials are presented in Table 4.2.3.1.

4.2.4 Discussion

With respect to the remains of earthworms in mammalian faeces, I was unable to confirm the findings of Brockie (1959), Bradbury (1977), Kruuk and Parish (1981) on other mammals. Earthworms could not be identified in the bandicoot scats via gizzards or chaetae. Two explanations may account for this:

(1) earthworms are totally digested including gizzards and chaetae;

(2) the method employed in scat analysis is not suitable for detecting chaetae or gizzards.

TABLE 4.2.3.1 Results of individual digestibility trials on two specimens of *P. gunnii* and two specimens of *I. obesulus*.

	Specimen	Identifiable Structures	
		Cockroach	Earthworms
Trial 1			
Earthworm only	*P. gunnii* No. 1		0
	P. gunnii No. 2		0
Trial 2			
Cockroach only	*P. gunnii* No. 1	0	
Trial 3			
Cockroach only	*I. obesulus* No. 1	3 tibias 1 tibia 1 femur	
	I. obesutus No. 2	0	
Trial 4			
Earthworm & Cockroach	*I. obesulus* No. 1	3 tibia 1 femur 1 mandible	0
	I. obesulus No. 2	2 tibia 3 femurs	0
Trial 5			
Earthworm & Cockroach	*I. obesulus* No. 1	2 tibia 3 femurs 3 mandibles	0
	I. obesulus	0	0

Heinsohn (1966) reported considerable quantities of earthworms in stomach contents of *Isoodon obesulus* and *Perameles gunnii*. With this knowledge, it was considered necessary to adopt a technique known to detect chaetae or gizzards from the scats of mammalian predators. The technique is similar to that applied by Kruuk and Parish (1981) on the Badger, *Meles meles*. Hence the technique involving sieving would appear adequate for detecting chaetae or gizzards if present. Dr. J. Hickman (personal communication 1985) considers that earthworm chaetae could only be identified by a floatation technique; however, Brockie (1959), Kruuk and Parish (1981) did not find this necessary.

The alternative view is consistent with the observations of Hall (1980b). In his study of the diets of two Dasyurids, *Antechinus stuartii* and *Antechinus swainsonii*, he found earthworms were common in the stomachs of *A. swainsonii* but not in scats. Hall (1980b) considered soft-bodied prey such as earthworms may be totally digested, and hence overlooked in faeces. Furthermore, although Bradbury (1977), Kruuk and Parish (1981) detected earthworm in the hedgehogs diet via chaetae and gizzards, Brockie (1959) fails to mention gizzard rings and stated that the only indication that hedgehogs had fed on earthworms was through chaetal presence. Whether differential digestibility exists in a species between two localities is not known but Hansson (1970) demonstrated that the use of conversion factors for micro-analysis of rodents fed on grasses may be erroneous due to different fragmentation at different seasons.

In comparison to the fraction of positively identified structures from insects examined in scats collected from the field, the number of identifiable structures collected from bandicoots fed solely on cockroaches was extremely low. Whereas whole legs, mandibles and other mouthparts, whole wings from various insect orders often appeared in scats from the field, the only whole structure which appeared from cockroaches was mandibles. This is not so surprising when considering cockroach anatomy. A majority of cockroaches supplied were large adults which, in spite of their relatively soft bodies, demand considerable mastication. No cockroach tarsi were recovered from scats, despite being represented in scats from the field, from other insect orders.

Cockroaches would appear to be an unsuitable representative for a majority of insect fauna. Despite being relatively large and soft-bodied, the wing structure is considerably different from that of other insect orders. The tegmina (forewing) is strongly sclerotized offering considerable resistance to digestion but is easily fragmented because of its large size. However, the hind wing is membranous (C.S.I.R.O. 1970), offering little digestive resilience.

Cockroaches would appear only suitable in establishing correction factors if preyed upon by the predator in question. Neither species of bandicoot were observed consuming cockroaches in this study under field situations. However cockroaches were sampled in pitfall traps on the wet heath study site in late spring whereas scat sampling was conducted in early spring, hence cockroach consumption could have occurred in late spring. The most expedient way of establishing a correction factor for cockroaches would apparently be as follows: over a large number of trials provide a known number of cockroaches, calculating the number of femurs or tibias consumed. The number of femurs or tibias detected in faecal analysis should be divided by the number consumed, then by six to establish a conversion ratio of the cockroach number consumed. This was not applicable to the method of quantification elected in the present investigation (Chapter 7).

Fox and Archer (1984) evaded the problem of differential digestibility by selecting the minimum number of individuals in any diet category in determining the number of prey items in the diets of *Sminthopsis murina* and *Antechinus stuartii*. This method of analysis is likely to underestimate the importance of soft-bodied animals providing little digestive resistance. However, for comparative purposes, assuming no differential digestibility between species in attempting to obtain quantitative data for analysis and testing, it can harvest useful information (see Fox and Archer 1984).

Soft-bodied prey may possibly be detected by the antibody technique applied by Davies (1969) and Reynoldson and Davies (1970). Anti-sera against prey species can be obtained by injecting into a vertebrate (usually a rabbit) a precipitated prey protein (antigen) which stimulates the production of a protein (antibodies) which specifically reacts with

the antigen. The anti-sera must be separated from the serum after bleeding the mammal and can be used to detect the presence of prey antigens in predators gut contents (located by a positive precipitation reaction). If the technique can be successfully used in faeces it would be highly suitable for a study of this kind, where specific quantities of prey items are not required.

Furthermore, estimating the proportions of various parts of plant species in the diets of *I. obesulus* and *P. gunnii* by faecal analysis could be considered by the technique similar to Storr (1961) and Dunnet *et al.* (1973).

CHAPTER 5

STUDY SITE DESCRIPTION FOR DIETARY ANALYSIS

CHAPTER 5

STUDY SITE DESCRIPTION FOR DIETARY ANALYSIS

5.1 General (Tasmania)

The Tasmanian climate is classified as temperate marine, the island situated between 40° and 43.5° south of the Equator.

Jackson (1965) recognised three main vegetation formations: austral montane, temperate marine, and sclerophyll forest. Many sub-forms ecotonal between these formations exist and do not easily occupy one formation due to the occurrence of environmentally induced and fire determined disclimaxes which prevent the climate's full expression. However, six categories are recognised: rainforest, sclerophyll forest, moorland, sedgeland, coastal heath and cleared land (Jackson 1965).

5.1.1 Location and Topography

The study sites, situated 3 km east of Huonville, along Glen Huon Road, lie within the Huon Valley in southern Tasmania (Chapter 1.2.1). Bordering the study sites of the valley are Mt. Misery (696 m) to the north, and Channell's Hill (476 m) to the south of the Huon River, which bisects the valley. The study sites are located on the southern flats of the river and are approximately lat. 43°01'11"S, long. 147°00'45"E (Tasmania Department of Mines 1981). An aerial photograph (February 1981) and a map of the study region is presented in Figs. 5.1.1.1 and 5.1.1.2 respectively. The three study sites are situated on a gentle slope at sea level altitude.

5.1.2 Geology

The geology of the study area (south of the river) comprises extensive beds of alluvium, river terrace deposits. The wet heath site possesses some influence from gravel and boulder beds, predominantly siliceous clasts of the Quarternary period (Tasmania Department of Mines 1981). Soils of all study sites are likely to be influenced by the landuse of the study site (Chapter 5.2).

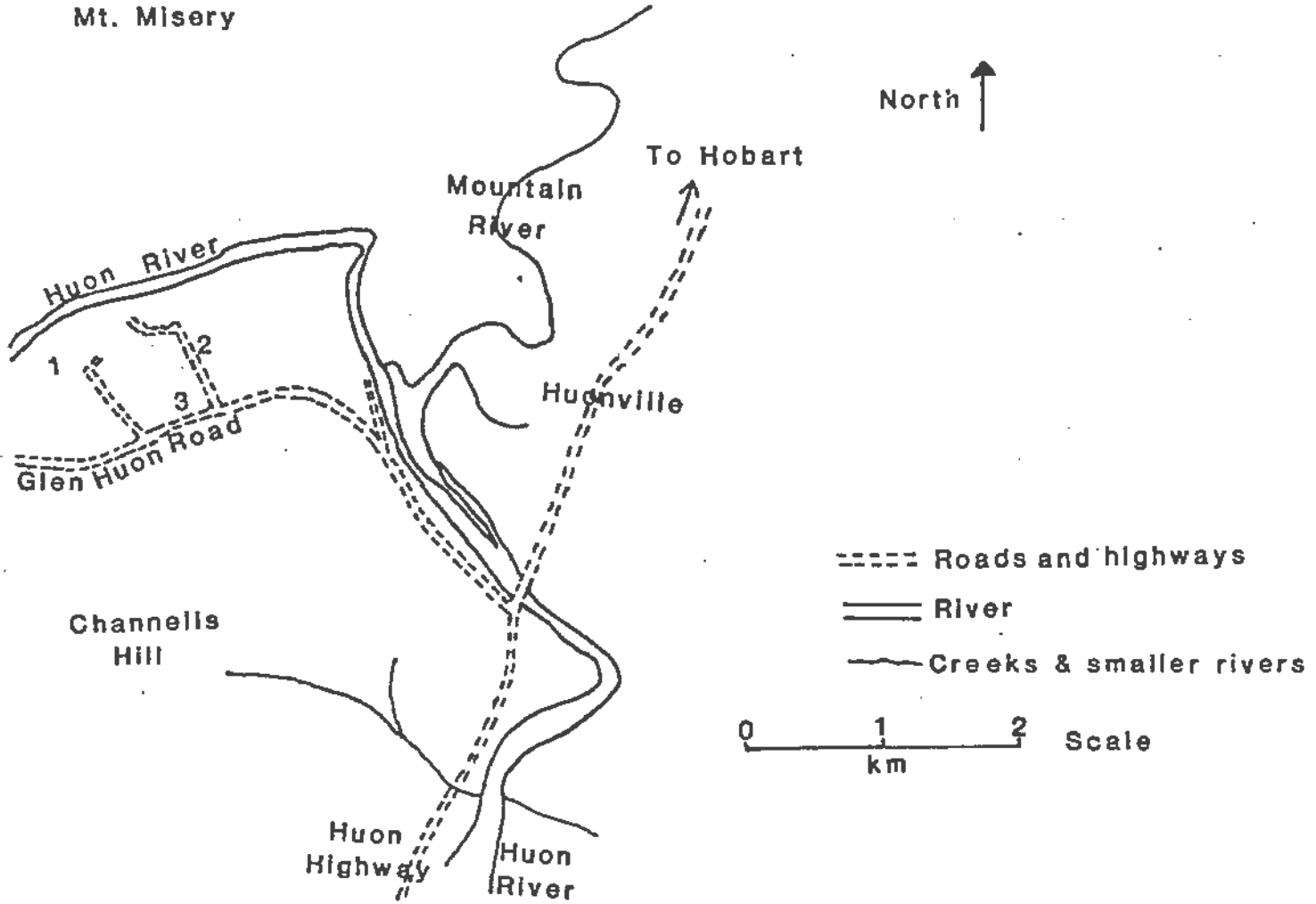


FIG. 5.1.1.2 Map of the study region showing the localities of the study sites (1, 2 and 3).

5.1.3 Climate

Weather data for the study region were obtained from the Tasmanian branch of the Commonwealth Bureau of Meteorology in Hobart. Long-term average monthly rainfall for the period 1962 to 1984 was procured for the Huonville station (lat. 43°02'S, long. 147°03'E) and is shown in Fig. 5.1.3.1 together with total monthly rainfall for January and the preceding months of the investigation. Huonville possesses a mean annual rainfall of 732 mm receiving, on average, the greatest precipitation in the months July, August and September. Rainfall was well above average prior to commencement of the investigation but was approximately on or below average thereafter.

Huonville does not possess a temperature station, hence temperature data are presented for Grove research station (lat. 42°59'S, long. 147°05'E), approximately 25 km south of Huonville. The Grove climate is likely to be more maritime in nature due to its closer sea locality. Long-term mean monthly maximum and minimum temperatures for the period 1952 to 1984 and mean monthly maximum and minimum temperatures for the period of the study are presented in Fig. 5.1.3.4. Mean maximum and minimum temperatures are, on average, highest in January and February and lowest in June and July.

5.1.4 Vegetation and Landuse

Much of the Huon Valley consists of cleared land under development for horticulture and grazing by felling forest (Jackson 1965). In particular, the Huon Valley is a rich apple growing orchard district (Gilbert 1965), while timber extraction is still in progress.

The vegetation surrounding the valley comprises predominantly rainforest (Gilbert 1965; Jackson 1965); however Jackson (1965) claims that the relationship between rainforest and sclerophyll forest is ill-defined because of the mosaic produced by soil fertility, aspect and fire. The vegetation present over most of the study area is likely to have been rainforest with a riparian influence prior to clearing.

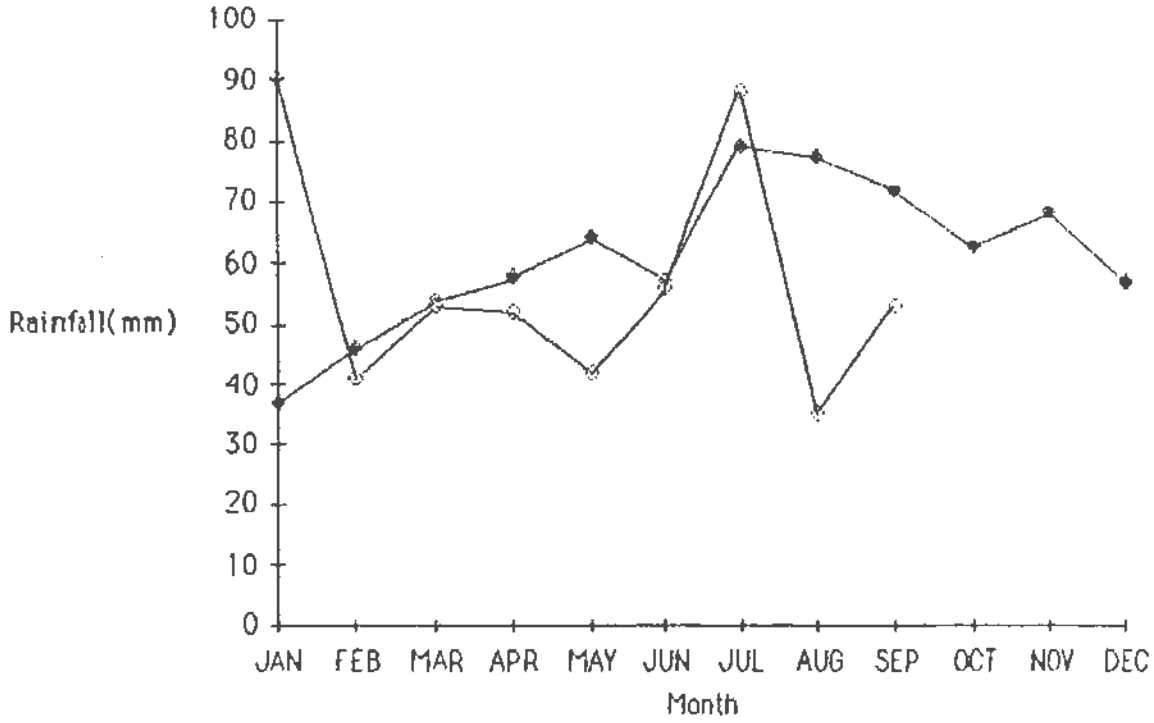


FIG. 5.1.3.1 Long-term average monthly rainfall (mm) for Huonville for the period 1962 to 1984 (solid diamonds) and the mean monthly rainfall totals for January and the period of the study (open diamonds).

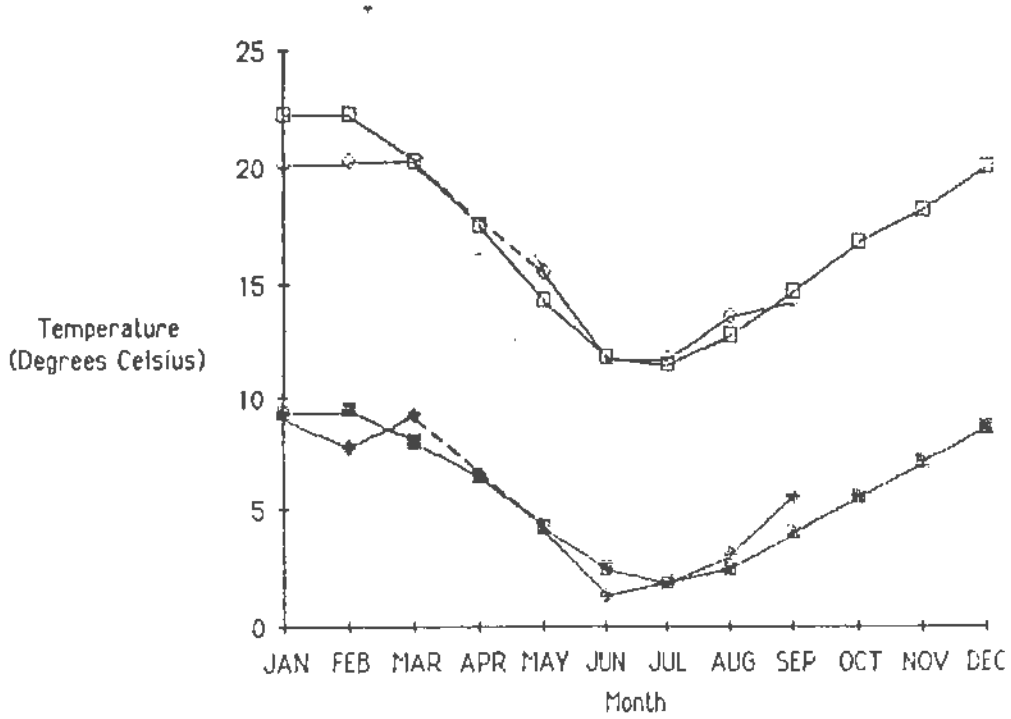


FIG. 5.1.3.4 Long-term mean monthly maximum (open squares) and minimum (solid squares) temperatures for Grove for the period 1952 to 1984. Mean monthly maximum (open diamonds) and minimum (solid diamonds) temperatures for the period of the study. A broken line indicates no record available for the intervening month.

5.2 Study Site Choice

Three study sites were selected for the following reasons:

(1) Sympatric populations of bandicoots were known to reside on at least two of the sites (Chapter 2.1).

(2) The variability of the three sites provided for an interesting comparison between three vastly differing vegetative complexes of differing age classes within close proximity to one another (see Plates 4-6).

5.2.1 Study Site 1 (Wet Sclerophyll Forest - Open Pasture): Description

The common names of the dominant plant species present are those utilised by Curtis (1963, 1980), Willis (1978), Costermans (1981) and Curtis and Morris (1981). A full botanical list of plant species collected from the three study sites is presented in Appendix C.

The wet sclerophyll forest resided in the north-western section of a pastoral paddock owned by Mr. Max Burton.

The dominant canopy consisted of mature Swamp Gum (*Eucalyptus ovata*) with a secondary understorey of the rainforest species, Silver Wattle (*Acacia dealbata*), Blackwood Wattle (*Acacia melanoxylon*), Dogwood (*Pomaderris apetala*) and Currajong (*Asterotrichion discolor*). The shrub layer included the Wattle, Prickly Moses (*Acacia verticillata*) with a dense Blackberry (*Rubus fruticosus*) layer. The dominant sedge present was the Tall Sword-sedge (*Lepidosperma elatius*). Pasture-grass (*Dactylis glomerata*), Annual Meadow-grass (*Poa annua*) and various herbs dominated the field layer of the pasture.

The forest graded into an open forest-pasture association with a scattered dispersion of blackberries. A diagram of the study site is presented in Fig. 5.2.1.1.

Adjacent fields formerly supported orchards but are now employed for grazing. The forest was burned during the 1967 bushfires (Mrs. F.

Burton, personal communication 1985).

5.2.2 Study Site 2 (Regenerating Wet Sclerophyll Forest-Golf Course Fairways): Description

Study site two was situated on the Huon Valley Golf Course (Fig. 5.2.2.1). A small fenced-off area adjacent to open fairways constituted a regenerating wet sclerophyll forest with the occasional heath undertone. The southerly portions of the site were typically tussocky in nature with Spear-grass (*Stipa* sp.) being prominent. The forest appeared to be intermediate in age between sites one and three.

The dominant canopy contained Swamp Gum (*Eucalyptus ovata*) and the occasional Messmate (*Eucalyptus obliqua*) sapling. Silver Wattle (*Acacia dealbata*) and Prickly Moses (*Acacia verticillata*) and the Tea-tree Manuka (*Leptospermum scoparium*) formed a secondary layer. Various shrubs compiled a dense shrublayer: the Peas, *Pultenaea juniperina* and *Pultenaea stricta;* the heaths, *Epacris impressa* and *Epacris lanuginosa; Hibbertia empetrifolia;* Wiry Bauera (*Bauera rubioides*), and Blackberry (*Rubus fruticosus*). The Tall Sword-sedge (*Lepidosperma elatius*), the Sag (*Lomandra longifolia*) and the Flat Cord-Rush (*Restio complanatus*) constituted the sedge layer. The field layer possessed a conspicuous layer of the Common Bog Rush (*Schoenus apogon*), the Blue Tussock-grass (*Poa poiformis*), Couch-grass (*Cynodon dactylon*) and various herb species.

5.2.3 Study Site 3 (Regenerating Wet Heath-Pasture): Description

Approximately two years before the present investigation, the land supporting the vegetation on this site possessed timber trays utilised in timber storage for the close-by William Lovell's Timber Mill. These were removed and the vegetation allowed to regenerate from virtually bare ground (Mr. W. Lovell, personal communication 1985). The tallest germinating Swamp Gum (*Eucalyptus ovata*) seedlings were approximately 10 m tall during the course of the study (Fig. 5.2.2.1).

A sparse to dense layer of *Pultenaea stricta, Epacris lanuginosa,* Dolly Bush (*Cassinia aculeata*), Prickly Moses (*Acacia verticillata*),

Blackberry (*Rubus fruticosus*) and young Swamp Gum seedlings formed a low wet heath. Manuka (*Leptospermum scoparium*) and the Scented Paperbark (*Melaleuca squarrosa*) bordered southern portions of the site. Parrot Food (*Goodenia ovata*) replaced some of the abovementioned shrubs as soil verged into gravel beds. A dense sedge and rush layer existed in parts of *Lepidosperma elatius*, *Lomandra longifolia* and *Restio complanatus*. *Schoenus apogon* and the grass, *Agrostis capillaris*, formed the dominating species of the field layer with the annual, Silvery Hair-grass (*Aira caryophylla*). Adjacent to, and dominating the pasture was Couch-grass (*Cynodon dactylon*) with the Austral Rush (*Juncus australis*).

Portions of the three study sites were subject to inundation during winter and spring months.

PLATE 4 Study site 1 - Max Burton Property Site
Two photographs illustrating vegetation formations on the site. Dense, wet sclerophyll forest merging into open pasture (top). Note the dense shrub layer of blackberries. A view of a portion of the forest itself (bottom).

PLATE 5 Study site 2 - Huon Valley Golf Course site
Golf course fairways where both species of bandicoot were occasionally seen foraging, adjacent to the study site (top) consisting of a regenerating wet sclerophyll forest. The oldest trees on the site are *Eucalyptus ovata* (Swamp Gum). A view of the trapping site itself (bottom). Note the dense, sedgey understorey.

PLATE 6 Study site 3 - William Lovell's Timber Mill site
Photographic description of the wet heath-pasture site.

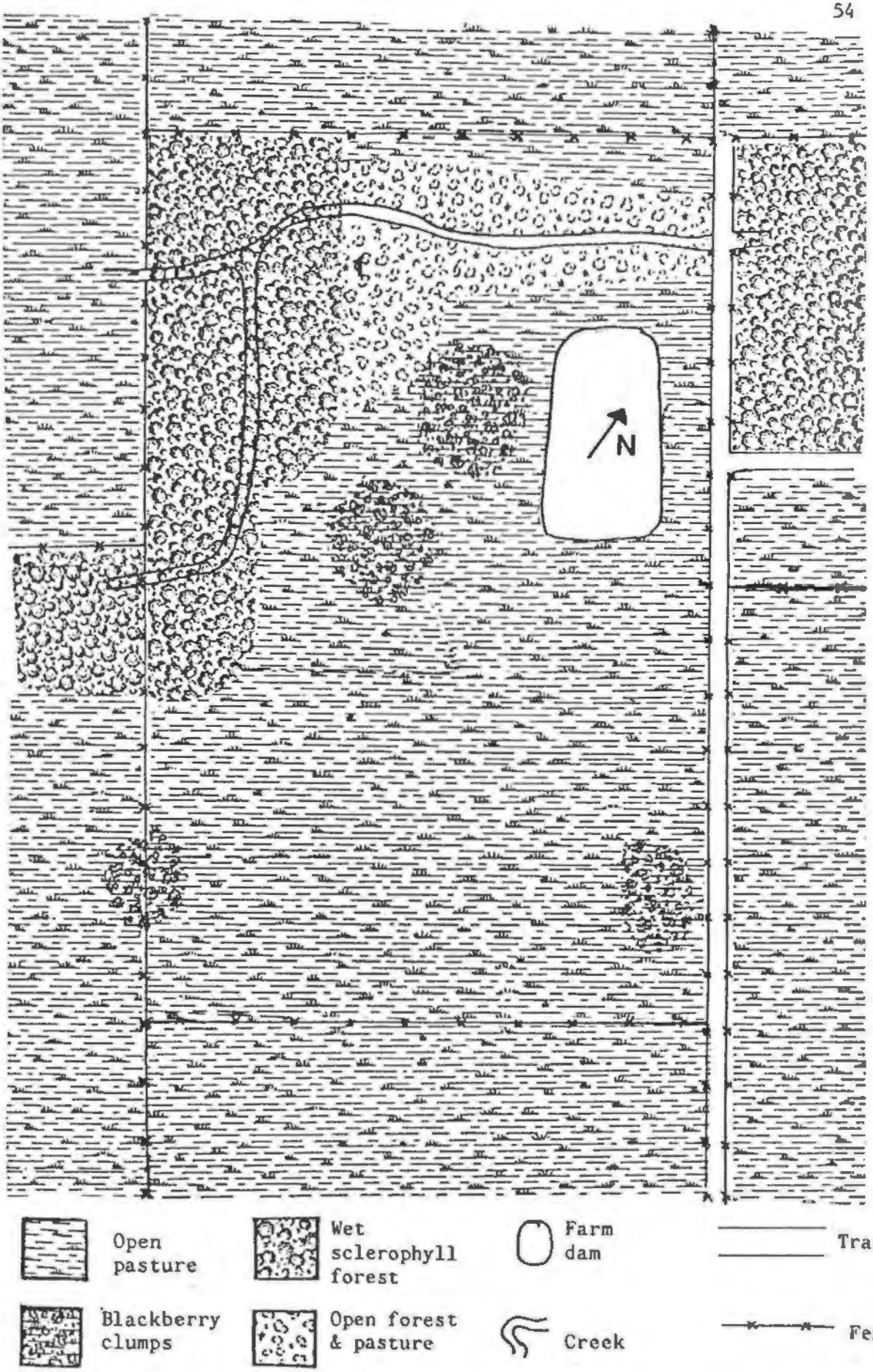


FIG. 5.2.1.1 Diagrammatic view of vegetation on study site number 1 - Max Burton property. Scale: 1:1375.

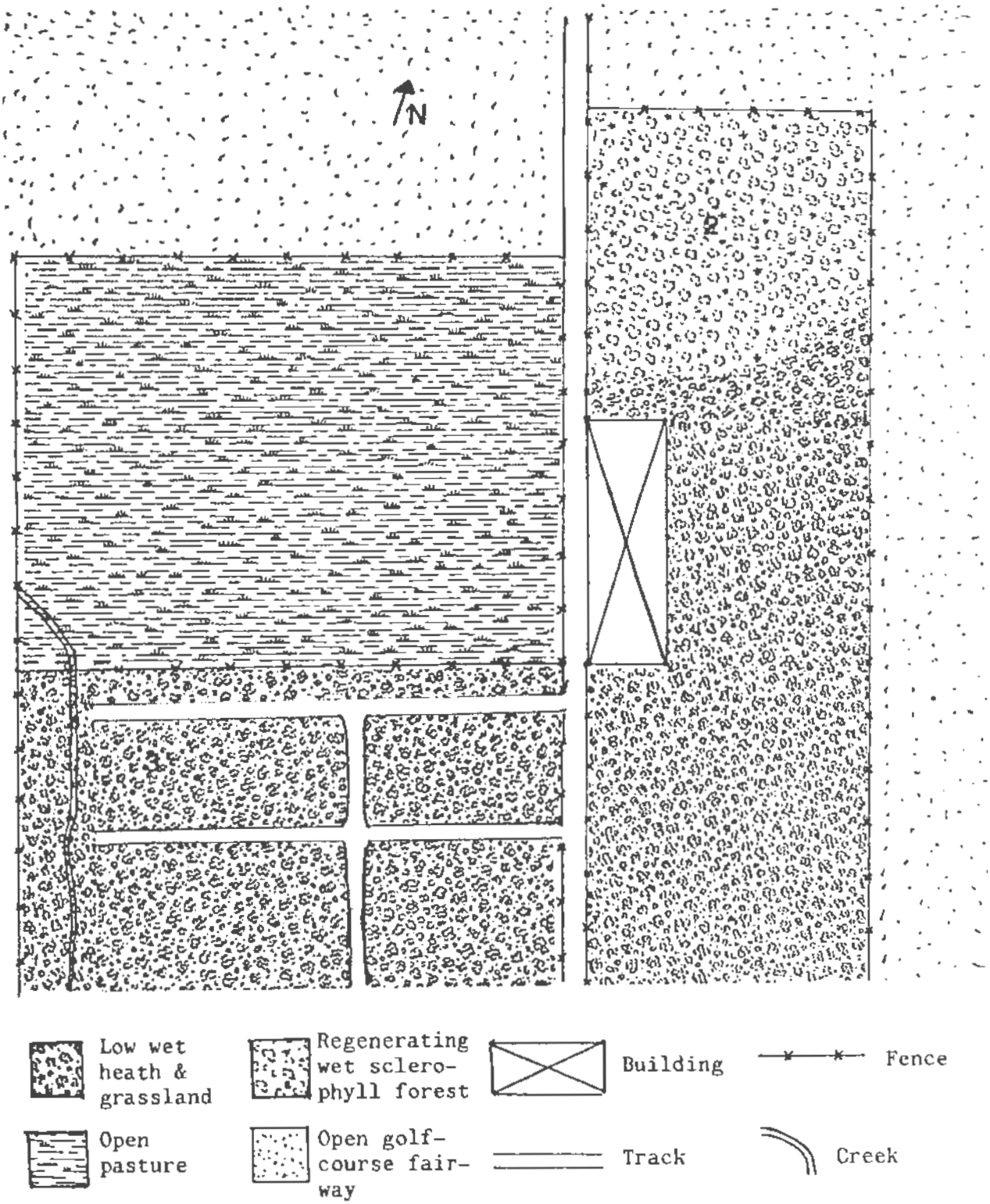


FIG. 5.2.2.1 Diagrammatic view of vegetation on study sites 2 and 3 - Huon Valley Golf Course and William Lovell's Timber Mill. Scale: 1:1834.

CHAPTER 6

TRAPPABILITY OF ANIMALS

CHAPTER 6

TRAPPABILITY OF ANIMALS

6.1 Comparative Trapping of Bandicoots

6.1.1 Introduction

Imperative in the present investigation was that animals could be trapped for positive identification and that sufficient numbers of both species be obtained for comparative purposes.

Gordon (1971) presents a summary of trappability of the Northern Brown Bandicoot, *Isoodon macrourus*. He considered that bandicoots were initially cautious prior to their first capture, but thereafter were not hesitant to enter traps. Furthermore, social inhibition was of only minor importance in preventing an animal entering a trap and the animals chances of encountering a trap was the major factor affecting its trappability.

The following section presents the trappability of bandicoots on the three study sites at Huonville.

6.1.2 Materials and Methods

The methodology employed in trapping, bait used, type of trap, animal restraining procedures have been described in Chapter 2.1.

A 80 x 75 m trapping grid was established on the Burton property using a 30 m marking tape. Five rows of six lines of traps were spaced at 20 m between rows and 15 m between lines. However dense vegetation occasionally resulted in a more variable interval.

A trapping grid was considered impractical on the golf course study site because of the relatively small area being sampled. Instead 16 traps were set at various positions suggestive of bandicoot activity e.g. runways, diggings etc. During winter and spring sampling, three additional trap sites were established on the golf course fairways.

The five by four trapping grid created on the regenerating heath plot measured 60 x 60 m with 15 m between rows and 20 m between lines. Hence the total number of trap stations established on study sites one, two and three were 30, 19 and 20 respectively.

Red ribbons were employed to mark trap stations, and once established, trap sites were utilised for the remainder of the study.

6.1.3 Results

6.1.3.a Study Site 1 - Wet Sclerophyll Forest - Open Pasture

Figure 6.1.3.1 presents the minimum number of animals known to be alive and at risk of capture on the study site (MNA). Experimental removal of two *Isoodon obesulus* occurred at the conclusion of the autumn trapping session and were not returned to the site until late winter. The winter sampling indicated that the territories occupied by these two individuals had not been filled with the only specimen captured being the individual not removed from the site. The MNA for the spring session had returned to three with only one of the re-entered individuals being re-caught.

Only one individual *Perameles gunnii* was trapped on study site one over the entire study. This individual trapped during winter sampling appeared to be a juvenile female.

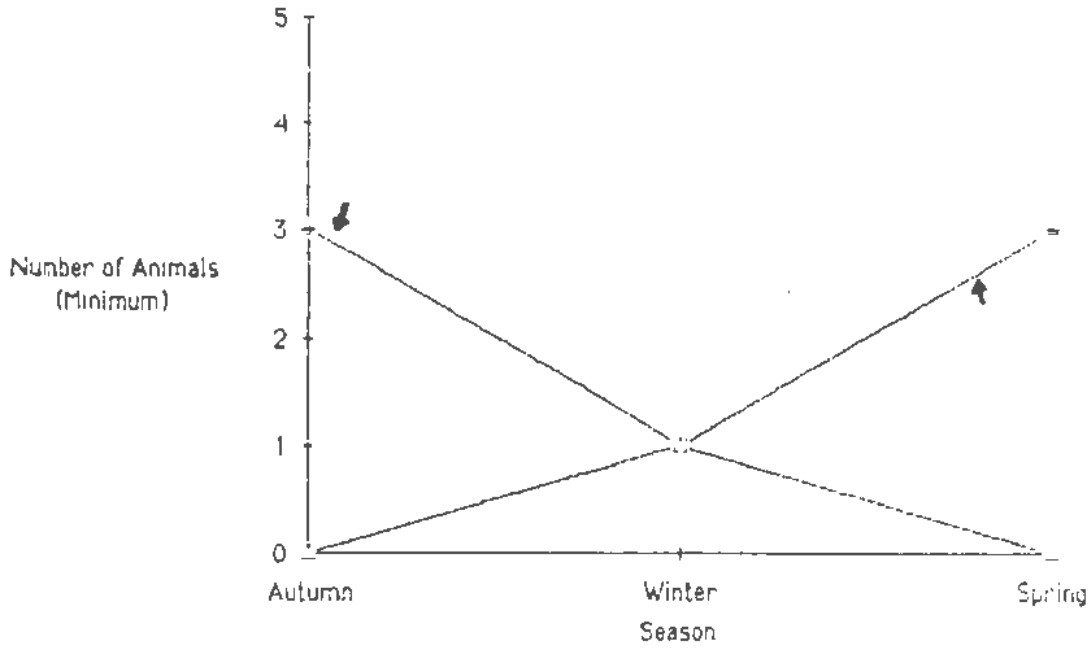


FIG. 6.1.3.1 Minimum number of animals known to be alive and at risk of capture on the wet sclerophyll forest-open pasture study site (no. 1). Solid squares represent *I. obesulus*; open triangles, *P. gunnii*. Arrows directed downwards indicate removal of specimens for investigations in captivity. Arrows directed upwards indicate re-entry into population of captive specimens. (For an explanation see text.)

6.1.3.b Study Site 2 - Regenerating Wet Sclerophyll Forest - Golf Course Fairways

Trapping results indicated that the resident Brown Bandicoot MNA for this study site was five during autumn and winter sampling sessions (Fig. 6.1.3.2). However, the MNA for Brown Bandicoots had declined to zero by the spring field trip. The MNA for Barred Bandicoots fluctuated from five in autumn to one in winter and four in spring.

One *P. gunnii* and one *I. obesulus* were removed from the study site after the autumn sampling session. Both specimens subsequently died in captivity. An additional *I. obesulus* was removed for captive investigations following the winter field trip and released following the spring trapping session.

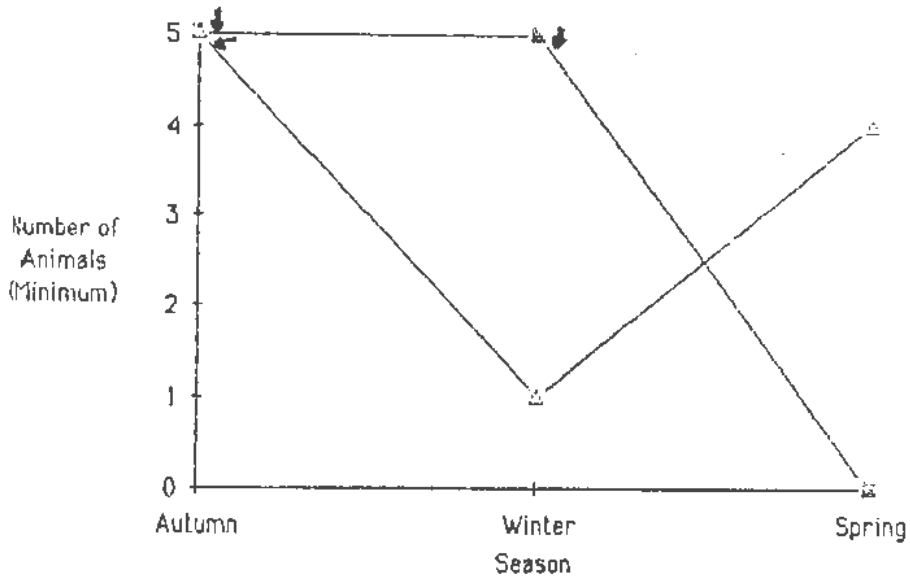


FIG. 6.1.3.2 Minimum number of animals known to be alive and at risk of capture on the regenerating wet sclerophyll forest - golf course study site (no. 2). Solid squares represent *I. obesulus;* open triangles *P. gunnii.* Arrows indicate removal of specimens for investigations in captivity. (For an explanation see text.)

6.1.3.c Study Site 3 - Regenerating Wet Heath - Pasture

A decline in the MNA for Brown Bandicoots by the spring session was also detected on this study site after remaining constant during autumn and winter (Fig. 6.1.3.3). Barred Bandicoots were not captured on the heath site. Furthermore, no spotlight observations were obtained of *P. gunnii* on the site or adjacent pastures suggesting complete avoidance of this site, although denser low vegetation on the plot itself did render spotlight surveys difficult.

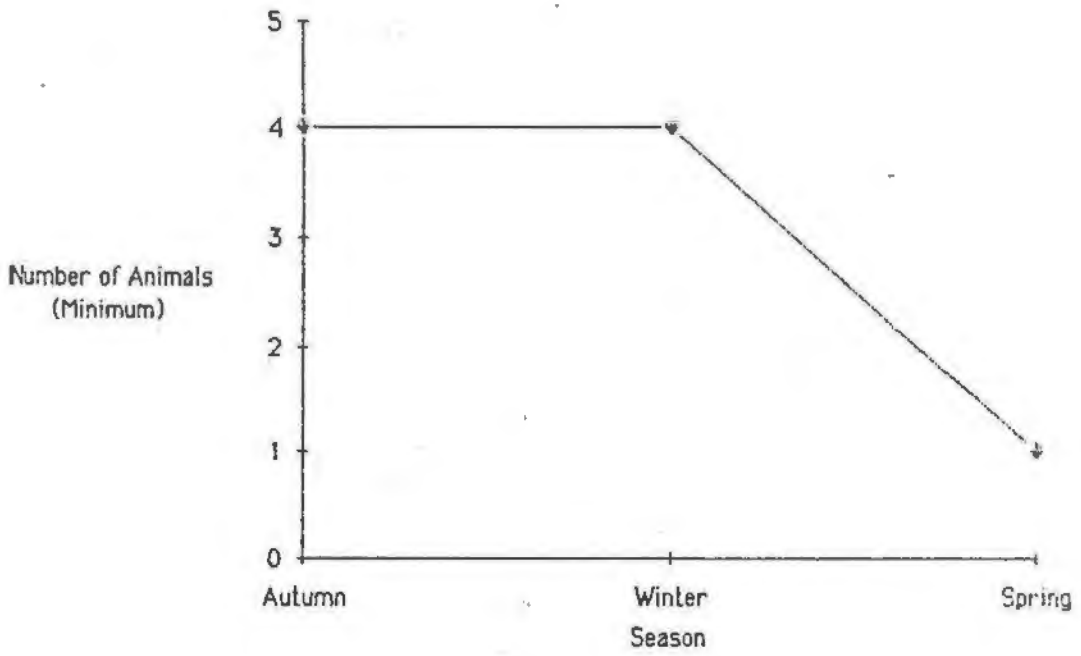


FIG. 6.1.3.3 Minimum number of *I. obesulus* known to be alive and at risk of capture on the regenerating wet heath study site (no. 3).

6.1.3.d Overall Trapping Results

The total, seasonal number of captures of *I. obesulus* and *P. gunnii* on each study site is shown in Fig. 6.1.3.4. The total number of captures remained higher for *I. obesulus* on all study sites in all seasons exempting the spring sample for the regenerating forest site when *I. obesulus* appeared to be absent, and during the winter session for the wet sclerophyll forest site when equal captures of both species were recorded.

Eighteen of the 20 captures of *I. obesulus* on the wet heath site were females. Only two individual male specimens were detected on this site. One, an unknown male was captured during the autumn trapping session, the other a transient from the golf course study site in the winter sample. In contrast, 11 of the 13 captures of *I. obesulus* on the regenerating wet sclerophyll study site were male. However, the seasonal number of individuals of either sex captured on both sites is too small to examine statistically whether a difference existed between

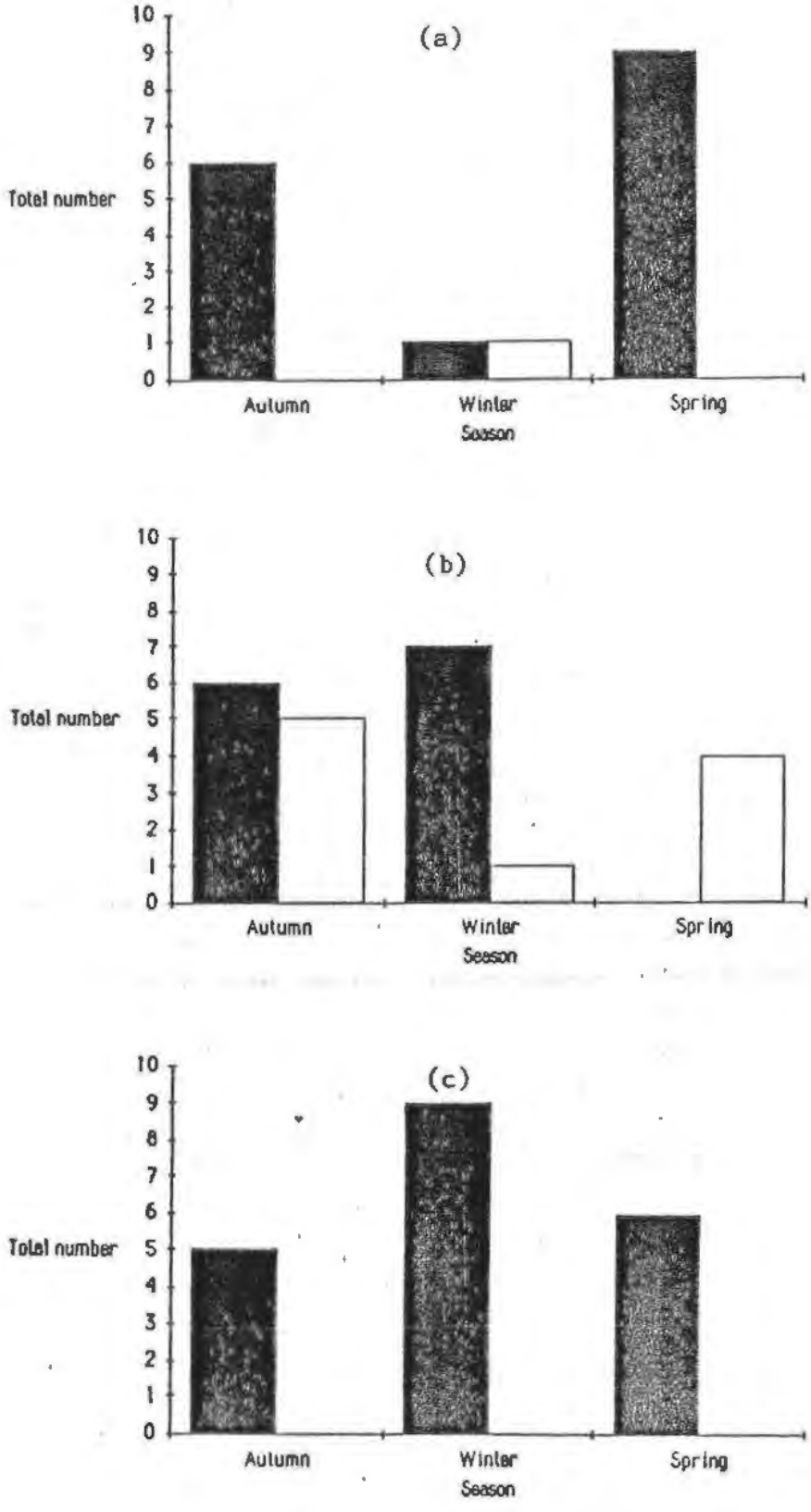


FIG. 6.1.3.4 Total number of captures of *I. obesulus* (solid bars) and *P. gunnii* (open bars) recorded on (a) study site 1 - Wet sclerophyll forest - open pasture;
(b) study site 2 - Regenerating wet sclerophyll forest - golf course fairways;
(c) study site 3 - Regenerating wet heath.

the trappability of individual males and females on either site.

Seven (14.58%) of the 48 captures of *I. obesulus* occurred during daylight hours suggesting some diurnal activity in this species. Brown Bandicoots were detected in traps as early as 1530 h (while rebaiting). It was not known for how long these animals had been in the traps.

6.1.4 Discussion

By comparing the total seasonal number of captures of *I. obesulus* and *P. gunnii* with the MNA for each species the relative trappability of individuals can be ascertained. The Brown Bandicoot population appeared to habituate to trapping with individuals being readily re-trapped during a session. In contrast, *Perameles gunnii* did not appear to accustom to trapping with no individuals being re-trapped during a session of the entire study.

The effect one species has on the other is not known for the two species in question, but it is possible that *I. obesulus*, by its mere presence, occupying a trap inhibited the number of traps potentially available for *P. gunnii*. Consistent with this view is the finding that *P. gunnii* captures were higher when *I. obesulus* MNA appeared to be lower e.g. study site 2, autumn and spring. An alternative explanation is that trap numbers in open areas e.g. golf course fairways, were not sufficient to encounter foraging *P. gunnii*. Further sampling could be conducted to attain the answer to the above explanations.

Barred Bandicoots appear to possess an extremely nervous disposition relative to that of Brown Bandicoots, not adapting well to a captive environment (Chapter 2.2). Hence, *P. gunnii* may be simply more trap-shy than *I. obesulus*. A combination of the above factors may have contributed to the relatively lower trappability of *P. gunnii*, together with the presence of non-bandicoot species.

Only one of the two *I. obesulus* individuals re-entered into the population and potentially re-trappable was recaptured on the wet sclerophyll forest study site. The sample size is too small to conclude

that removing and replacing the animals had a detrimental effect on their survival. However, the remaining two individuals trapped were not residents previously encountered hence may have filled at least two of the vacant territories in this population prior to release of the captive individuals.

The apparent partitioning of habitats by *I. obesulus* with predominantly females occupying the regenerating heath site and males the older vegetative study site is interesting because dietary analysis revealed heath animals to be selecting from a wider range of prey available. Braithwaite and Gullan (1978) and Stoddart and Braithwaite (1979) have demonstrated that *I. obesulus* possesses a clear preference for a younger component of heathland vegetation in eastern Victoria. In a follow-up study, Opie (1980), showed that many of the commonly occurring invertebrates were more abundant in the young heath component. Furthermore, Stoddart and Braithwaite (1979) showed that smaller, younger females producing the bulk of the production of the young were more likely to be encountered in the young heath plot.

Recently burned scrub or heath is usually considered to have a high productivity (Jones *et al.* 1969). Heinsohn (1966) found that *I. obesulus* preferred recently burned scrub and heath in north-west Tasmania.

Stoddart and Braithwaite (1979) provide evidence that clearing has a more devastating effect upon the habitat than burning. Although abundance/biomass of invertebrate prey taxa was not estimated in the present study, a greater range of invertebrates appeared to be detected in pitfall traps and soil samples on the regenerating heath site relative to the other two study sites.

Although this could not be statistically examined, the author suggests that the constraints placed upon lactating females for protein requirements may possibly play a role in determining the response of Brown Bandicoots to the two study sites in closest proximity to one another, with females selecting the site of possible higher invertebrate productivity. Consistent with this is the observation that although certain taxa e.g. Chilopoda, Isopoda were readily discovered in pitfall

traps on all three sites, they were only detected in faeces of animals on the heath site (Chapter 7) suggesting that bandicoots were possibly selecting these prey with an additional requirement in mind (lactation).

The mean weight of initial, seasonal captures of females on the wet heath site was 700±91.73 (S.E.)g (n=8), with a range of 200-1125 g over the entire study. Stoddart and Braithwaite (1979) also revealed that smaller, younger females (450-600 g) were more likely to be captured on the young heath component in eastern Victoria. Where older, heavier females resided in the present investigation was not known. Further, more intensive and extensive sampling may provide the answers to the above questions, namely:

(1) Is the number of females trapped on the wet heath site statistically significantly different to the number of males encountered (vice versa for study site two)?

(2) What are the habitat preferences of older, heavier females?

(3) Does the relative invertebrate abundances/biomasses on the three study sites differ?

The apparent absence of *I. obesulus* from the golf course study site in spring is intriguing. Braithwaite and Gullan (1978) demonstrated that *I. obesulus* preferred dry communities. Since portions of this study site were inundated through much of winter and during the spring sampling session the Brown Bandicoots may have moved in search of drier communities.

The apparent absence of *P. gunnii* from the wet heath site may indicate that, unlike *I. obesulus*, this species is unable to utilize regenerating heathland, or that where two habitats such as a regenerating heath and an open area e.g. pasture, or as in this case golf course, are nearby, *P. gunnii*, in the presence of *I. obesulus*, may hold a distinct preference for the latter habitat. The overall effect may reduce competition by dispersing the two species over a wider range of optimal regimes.

The finding that *I. obesulus* exhibits some diurnal activity is consistent with Heinsohn's (1966) observations of daylight activity in this species. Furthermore, Brown Bandicoots were often active in holding cages and the enclosure at all times of the day during their period in captivity. It would be highly advantageous for an animal preferring low, dense vegetation to show some diurnal activity rather than an animal showing preference for open areas as displayed by *P. gunnii* in view of the greater risk of predation during daylight hours. Gordon (1974a) also demonstrated some departure from the normal nocturnal activity pattern in *Isoodon macrourus*. Unfortunately I was unable to determine for how long these animals had been in the traps, and hence the time of their emergence.

Hall (1980a) examined the diel activity of *Antechinus stuartii*, *Antechinus swainsonii* and *Rattus fuscipes* coexisting in southern Victoria by trapping for alternate 2 h periods until all 12, 2 h periods in a 24 h day were trapped repeating the procedure until each 2 h period was trapped twice in each sampling session. He was able to show that *A. stuartii* is predominantly nocturnal, *A. swainsonii* displayed even diel activity and *R. fuscipes* to be exclusively nocturnal. This technique could be used in conjunction with radio tracking to deduce the precise diel activities of *P. gunnii* and *I. obesulus*.

Moloney's (1982) captive trials displayed that *I. obesulus* emerged approximately 1 h after sunset whereas *P. gunnii* emerged much later (2.5 h) after sunset. The field investigations in the present study did not confirm this. *Isoodon obesulus* was never seen to emerge probably because of the greater use of vegetatively denser habitats. However, *P. gunnii* was seen to emerge just on or shortly after sunset in the field during autumn and spring field trips. Barred Bandicoots have also been observed emerging at dusk in northern parts of Tasmania (S. Bryant, personal communication, 1985). Bandicoots were not observed to emerge at all during the winter trapping session. Hence, it could be when temperatures are at their coldest that *P. gunnii* reduces its activity and emerges much later.

The possibility of temporal separation in foraging activity between *I. obesulus* and *P. gunnii* warrants further investigation for Lyne (1981)

has shown the complexity of activity rhythms of *I. macrourus* and *Perameles nasuta* in captivity.

CHAPTER 7

DIET

CHAPTER 7

DIET

7.1 Prey Selection

7.1.1 Introduction

Despite the overlapping distributions of several species of Australian bandicoots and bilbies, few comparative dietary studies have been undertaken. In fact little is known of the feeding biology of a majority of bandicoots. The diet is generally mixed between animal and plant matter, the broad term "omnivore" being devoted to bandicoots and bilbies (Wood-Jones 1924; Troughton 1965; Rayment 1954; Lyne 1964b, 1979; Gordon 1974b). However, Wood-Jones (1924) considered that bandicoots scratched at roots while seeking insects and were not in search of the roots themselves. Rayment (1954) states that bandicoots have been observed to devour many kinds of roots and bulbs, fungi, small birds, earthworms, seeds and insects of several families.

Sandars (1952) examined two stomachs of the Northern-Brown Bandicoot (*Isoodon macrourus*) from Queensland. One consisted largely of the fruit of the Wild Passion Fruit (*Passiflora foetida*), the other of Carabidae beetles (Harpalinae), Coleopteran larvae (Tenebrionidae, Scarabaeidae), two types of Lepidopteran larvae, slugs and a lizard. Harrison (1963) inspected 22 stomachs of *I. macrourus* from near Innisfall. The diet appeared nicely balanced between insect and plant material, the latter category including raspberry fruits, seeds, root material and sugar cane fibre.

McKeown (1951) considered the practical importance of the Long Nosed Bandicoot (*P. nasata*) in Sydney in destroying harmful garden insects and larvae e.g. "army-worm" caterpillars (Noctuidae), Scarabaeidae larvae, the Scarabaeid beetle *Heteronychus sanctae-helenae*, fruit-tree root weevils (Curculionidae). The single scat also contained a small quantity of fibrous grass roots.

The Golden Bandicoot, *Isoodon auratus*, of Western Australia is known to include small vertebrates in its diet. McKenzie (1983) has shown the diet in the Kimberleys consists of termites, centipedes, insect larvae and plant material, while populations on Barrow Island are known to consume ants, moths, turtle eggs, small reptiles and the Common Rock-rat (*Zyzomys argurus*) in addition to roots and tubers.

The diet of the Bilby (or Rabbit-Bandicoot), *Macrotis lagotis*, has been examined by Smyth and Philpott (1968) and Johnson (1980). The former found the diet to consist primarily of soldier and worker castes of two termite species and an ant species. Sporadic in their occurrence in faeces were Lepidopteran larvae and undigested plant tissue e.g. seeds, plant hairs. In addition Johnson (1980) found beetles, seeds, fruits, bulbs, a small amount of fungus and grass in scats. The preference for particular food items and dietary variation appeared to reflect seasonal and local food availability. Southgate (1985) recorded *M. lagotis* to be feeding predominantly on insects, but the diet was varied containing fire promoted food items.

Little information has accumulated on the diet of mainland *Perameles gunnii*; however studies currently in progress (Brown 1985) are aimed at this problem. In contrast extensive documentation of the diet of *Isoodon obesulus* exists in particular for Victoria but also for the Nuyts Islands (South Australia).

Watts (1974) examined 50-60 faecal pellets of *I. obesulus* from the Nuyts Islands and found them to comprise mainly insects, predominantly two or three species of Hemipteran (Lygaeidae), although Coleopteran beetles and Lepidopteran larvae were encountered. An appreciable amount of vegetable matter, primarily parts of the ice plant (*Cryophytum* sp.) was also eaten. A few small down feathers were detected in scats and probably arose from moribund or recently deceased penguin chicks occasionally encountered on the island.

On a heathland site in eastern Victoria, faecal analysis of *I. obesulus* showed that the root-feeding Melolonthine larvae (Scarabaeidae), was most prevalent in the diet in autumn and winter, while ant pupae, adult Scarabaeids and adult Hemipterans in spring and summer

(Opie 1980). Diptera, Tenebrionid larvae, earwigs and spiders were also taken. Subterranean fruiting bodies of hypogeous sporocarpic fungi (mainly *Endogone* and *Glomus*) were consumed during winter and spring when soil was moist. The fruits of *Cassytha* sp. (Lauraceae) were also eaten (Cockburn and Lee 1985). A follow-up study by Lobert and Opie (1985) revealed essential similarities in diet with the addition of vascular plant material.

The most intensive investigation to date on the diets of *I. obesulus* and *P. gunnii* in Tasmania was conducted by Heinsohn (1966) at Smithton, north-east Tasmania. Twenty-six stomachs of *P. gunnii* and 11 stomachs of *I. obesulus* showed that the major food items taken by both species comprised earthworms, adult beetles, Phalaenidae and other Lepidopteran larvae. The only difference to arise was the extensive feeding of *I. obesulus* on Scarabaeidae larvae. Substantial quantities of blackberry (*Rubus fruticosus*) and boxthorn (*Lycium* sp.) fruits were consumed when ripe. Minor food items taken were Elaterid larvae, Hepialid larvae, Dipteran larvae and small vertebrates (skinks and frogs).

Moloney (1982) was unable to ecologically segregate *P. gunnii* and *I. obesulus* by diet. In an unquantified account, ant species were the major food item probably associated with drought conditions prevailing during the study. Other items taken were Dipteran larvae, adult beetles, earthworms, Coleopteran larvae and plant material (seeds and grass pieces). Hence investigations to date have revealed the two to occupy similar dietary niches.

A quantitative investigation was undertaken into the diets of *P. gunnii* and *I. obesulus* by faecal analysis to examine the degree of ecological segregation exhibited by the two species. In addition, the relative availability of invertebrate prey items was measured to ascertain whether the bandicoots consume prey in proportion to their occurrence.

7.1.2 Materials and Methods

7.1.2.a Prey Identification

Faecal pellets were collected, where possible, from beneath the traps of live-trapped bandicoots. Pellets were stored in plastic vials containing 70% alcohol and transported to the laboratory labelled with locality, date, sex and species of capture.

Scat dissection was identical to that described in Chapter 4.2.2. Invertebrate fragments were identified by reference to descriptions and illustrations (C.S.I.R.O. 1970; Barnes 1974) and to a collection of specimens from pitfall traps and soil samples. Unidentified larval skins or invertebrate integument were stored in 70% alcohol for later identification.

An attempt was made to identify grasses consumed via a modification of Storr's (1961) epidermal strip technique as applied by Quin (1984):

(a) Faecal plant fragments were placed in a beaker containing 5 ml of nitric acid.

(b) The beaker was heated for 3-5 min, depending on leaf toughness, on a hot plate in a fume cupboard.

(c) When most of the mesophyll had broken down or the cuticle had begun to separate from the mesophyll, heating was ceased and water added to prevent further digestion.

(d) Cuticular strips containing enclosed epidermal pieces were placed onto a slide and any mesophyll remaining scraped off using a fine camel hair brush.

(e) Slide was placed in oven (50-60°C) for 5 min drying.

(f) Slide was removed from oven, Saffranin stain added to the strip using a pipette, and left for 30 min.

(g) Slide was immersed in 50% alcohol for 1 min.

(h) Slide was then placed in 80% alcohol for 1 min and then immersed in two changes of 100% alcohol for 30 sec each. Steps (g) and (h) gradually remove excess stain from the cuticular strip.

(i) Slide was immersed in two changes of xylene, 30 sec each to dehydrate the strip.

(j) A coverslip was placed over the strip using De Pex because it improves clarity of cuticular strips more than other mounting mediums.

(k) Cuticular strips obtained from dropping material were compared to a reference collection, consisting of epidermal strips from grasses collected from the study sites.

7.1.2.b Prey Availability

To attain the relative availability of invertebrate prey taxa of a predator which obtains food partially from the surface and partially from within the soil, it is necessary to devise a technique which samples surface and soil-dwelling invertebrates adequately. Hence pitfall trapping was conducted in conjunction with soil sampling.

Pitfall traps were 200 ml plastic party cups (65 mm diameter) set in the ground with their rims level with the soil surface with a splash of 70% alcohol for preservative. An 11 x 11 cm piece of cement sheet was placed over each cup with a prop (e.g. stone) in each corner to prevent excess rainwater from flooding traps while still allowing invertebrates to move beneath. Cups were placed within a 1 m radius of each trap station, three cups per station on study site one and two per station on study sites two and three, but were not set on the three trap stations established on the golf course fairways in winter. Hence, initially 90, 32 and 40 traps were set on study sites one, two and three respectively. However, normally a small proportion of cups became damaged or inundated hence reducing the operative number.

For convenience, pitfalls were normally left set between one field trip and the next, the duration being approximately one and a half to two months.

For comparison with dietary analysis, each trap station containing pitfall traps was regarded as a pitfall trap quadrat regardless of the number of cups set per station. Hence initially 66 pitfall trap quadrats were established i.e. one quadrat per trap station on each study site.

Moloney (1982) found the average depth of 196 bandicoot diggings in the wild to measure 48.28 mm, hence soil samples in this study were taken to a depth of 5 cm and were 25 x 25 cm^2. The contents of the quadrat were placed into plastic bags, noting soil and vegetation conditions prevailing at the time. These were normally collected during a bandicoot trapping session.

Initially, 25 soil samples were extracted from the wet sclerophyll forest-pasture study site in a grid formation with 15 m between five rows, and 20 m between five lines. Hence samples were taken from a smaller grid within the larger bandicoot trapping grid. The sample number was reduced during winter and spring to 20 by eliminating one diagonal of the grid. A similar technique was employed to excavate soil samples from the heath site with 16 samples taken from the main grid with 15 m between 4 lines and 20 m between 4 rows, except in winter when 15 quadrats were procured. Two rows of five quadrats spaced at 10 m intervals were obtained from the golf course study site exempting autumn when nine samples were collected.

Soil samples were collected in a way which hopefully sampled the entire trapping grids. However, quadrats were not taken from the golf course fairways themselves.

Invertebrates were pooled from cups for each pitfall trap station. Samples were hand-sorted and identified to, where possible, Family level. These provided a reference collection by which the majority of faecal fragments were identified.

7.1.3 Results - Prey Selection

7.1.3.a Results - Dietary Categories

Forty-eight faecal samples were collected from *Isoodon obesulus* and 10 from *Perameles gunnii*. In addition, the stomach contents of one *P. gunnii* was examined from a deceased animal discovered on the golf course. The samples were allocated to one of three habitat categories and one of three seasonal groups as is shown in Table 7.1.3.1.

Dietary taxa were expressed as the percentage of the total number of scats for a habitat or seasonal group containing that particular food item. Hence each faecal pellet was scored as a presence-absence for prey taxa. Although some quantification of invertebrate taxa was performed, this method of assessment reduces the error of miscalculating the number of Arthropods present in scats due to considerable fragmentation. Furthermore, it overcomes the obstacle of quantifying plant matter when it is impossible to determine accurately the number of plant items consumed.

Invertebrate taxa were considered separately if they occurred in 10% or greater of either faeces, soil samples or pitfall traps. Hence some invertebrate taxa were grouped to reduce the number of dietary categories to a workable size. Efforts were made not to excessively group taxa and therefore depart from the Family level of prey classification because Greene and Jaksic (1983) have demonstrated the benefit of a higher than ordinal level of prey identification. The conservative pooling of taxonomic prey categories is likely to reduce rather than emphasize differences in diet when comparing species (Fox and Archer 1984). Thirty-six prey categories were recognised and will be briefly discussed in the following section.

7.1.3.b Results - Notes on the Food Substances

Mature Coleoptera

This category includes those mature Coleopterans not already categorised. These included the families Scarabaeidae, Elateridae,

TABLE 7.1.3.1 Number of faecal pellets collected for each habitat type and season for *I. obesulus* and *P. gunnii*

Habitat	Autumn		Winter		Spring	
	I. obesulus	*P. gunnii*	*I. obesulus*	*P. gunnii*	*I. obesulus*	*P. gunnii*
Wet sclerophyll forest - open pasture	6	-	1	1	8	-
Regenerating wet sclerophyll forest-golf course fairways	6	4	7	1	-	5*
Regenerating wet heath-pasture	5	-	9	-	6	-

* includes 1 stomach sample

Chrysomellidae, Curculionidae (weevils) and Coleopterans too well masticated to identify in faeces. One *Isoodon obesulus* scat also contained a specimen of the Lucanidae family, probably *Phalacrognathus muelleri*. The most identifiable portions of integuments proved to be leg pieces and wings. Although the above identifiable families were not represented in faeces from *Perameles gunnii*, this was probably related to the small number of scats collected for that species.

E/S/C Larvae

This group was represented by Elateridae, Staphylinidae (Rove beetle) and Curculionidae (Weevil) larvae. The former two were represented in scats from both species, the latter only in faeces from *I. obesulus*. These were identified from larval skins/body plates and larval mandibles and head capsules (Curculionidae). The predominant item in this category found in scats was Staphylinid larvae.

Staphylinidae Beetles

Rove beetles were identified from faecal pellets of both *I. obesulus* and *P. gunnii* and were the most commonly occurring adult Coleopteran, identified in scats. These were most often identified via wing structure and venation, leg structure and large body segments.

Carabidae Beetles

Ground Beetles were the most frequently occurring identifiable adult beetles in Barred Bandicoot scats. Legs, wings and occasionally whole elytra were the most recognisable fragments.

Carabidae Larvae

Two species of Ground Beetle larvae were detected in pellets of *I. obesulus*; the most commonly occurring species found in scats of both species was identified via relatively large brown undigested skins.

Scarabaeidae Larvae

Scarabaeidae larvae were the most frequently represented Coleopteran prey item encountered in scats of both bandicoot species. Occasionally

larval skins persisted digestion in one piece with head capsules still intact. Mostly, however, if skins resisted digestion they were separated from the fragmented head leaving the heavily sclerotized mandibles as the sole positively identifiable structures.

Formicidae

Large ants (probably Bull Ants) were most commonly identified via large mandibles and leg fragments resilient to digestion. Smaller, black ants often occurred almost intact in faeces, probably requiring little mastication because of their small size.

Hymenoptera (Other)

This category included non-Formicid Hymenopterans, in particular bees and wasps from the family Ichneumidae and were detected from wing structure and venation and legs. Although occurring in approximately 30% of all *I. obesulus* scats they were not detected in *P. gunnii* faecal pellets. Brockie (1959) considered that hedgehogs would be unable to capture active bees and wasps and suggested these were dead or moribund when eaten.

Calliphoridae Larvae.

Blowfly larvae were well represented in faeces of *I. obesulus* and *P. gunnii* appearing quite resilient to digestion. Larvae appeared reasonably intact and were most easily identified by the pharyngeal head plate and mouth hook.

Diptera Larvae

This prey group comprised the remaining non-Calliphorid larvae and pupae of which a range existed in pitfall traps and soil samples but never in great numbers with the exception of Muscidae and Chironomidae larvae. Chironomidae larvae were most commonly represented in this category although other pupae were occasionally detected in scats. Skins appeared relatively resistant to digestion.

Diptera Mature

A range of Dipteran flies were collected from pitfall traps including Anispodidae, Heleomysidae, Calliphoridae and Phoridae being most prevalent. However the flies occurring most commonly in faeces were the dung or carcass inhabiting Sepsidae. In fact, 120 wings of this family were detected in the scat of one *I. obesulus*. Occasionally unidentified flies were detected and one *I. obesulus* scat contained the remains of a Blowfly. Wings were the identifiable structures appearing in scats.

Noctuidae

Lepidopteran armyworm caterpillars occurred more commonly in Barred Bandicoot scats. The larval skins and occasionally head capsules appeared quite resistant to digestion, the prominent setal plates allowing identification.

Hepialidae

Only two species of Corbie grubs (Lepidoptera) occur in Tasmania, Corbie (*Oncopera intricata*) and winter corbie (*O. rufobrunnea*), and are both pasture pests. They differ in their timing of life cycles (Entomology Division, Tasmania Department of Agriculture 1974). These were detected in both species in autumn and spring coinciding with larval availability. The large larval skins present in faeces suggest that the grubs provided considerable nutrition to the bandicoots in autumn and spring.

Hemiptera

Two families were detected in *I. obesulus* scats; Cydnidae and probably Lygaeidae, the latter not being represented in pitfall traps, however was present in one *P. gunnii* scat. Wings and legs appeared to resist digestion and fragmentation hence were easily identified. Pentamoidean nymphs were also detected in soil samples, but not scats.

Siphonaptera

Fleas appeared whole in bandicoot faecal pellets and were obviously eaten during grooming.

Chilopoda

Centipedes were only found in two *I. obesulus* pellets. In one the centipede skins resisted digestion; however in the second faecal pellet only the jaws were detected.

Isopoda

Slater bugs (Oniscidea) were only detected in a small number of faeces from Brown Bandicoots on the wet heath site. Body plate pieces and legs provided the easiest way of recognition.

Araneae

Spiders were identified in both *P. gunnii* and *I. obesulus* predominantly from the soft leg parts, in particular the characteristic tarsi; jaws were occasionally encountered in the scats.

Acarina

These were possibly derived from the pelage of bandicoots. However, some mites e.g. Strombidiform were detected in pitfall traps and soil samples. These usually appeared whole in faeces.

Collembola

Springtails were only represented in one scat each of the two species, in which they appeared whole and unmasticated, probably due to their small body size.

Larvae

This category was included to accommodate unidentified larvae occurring in scats and infrequent larvae from soil samples and pitfall traps which could not be allocated to one of the above larval categories e.g. other Lepidoptera larvae, unidentified larvae, the Coleoptcran

larvae Tenebrionidae and Chrysomellidae and Neuropteran larvae (Osmylidae).

Other Invertebrates

Infrequent invertebrates located in soil samples and pitfall traps e.g. Gryllidae (crickets and grasshoppers), Blattodea (cockroaches), Neuroptera nymphs (lacewings), Scorpiones (Scorpions), Diplopoda (millipedes), Platyhelminthes (flatworms), and unidentifiable invertebrate integument appearing in faeces. The only positively identified items in this category occurring in bandicoot faeces were of grasshoppers and crickets in *I. obesulus*.

Oligochaeta, Amphipoda and Gastropoda

These three taxonomic groups, although not represented in faeces (earthworm was detected in the stomach of one *P. gunnii*) warranted separate categories because of the large proportion of soil samples and/or pitfall traps occupied.

Blackberries

Faeces were often purply in colour when containing blackberry material. During autumn sampling, scats were burdened with blackberry seeds and skins, which had obviously resisted digestion.

Roots

Fibrous grass roots appeared to pass through the digestive tract unchanged. These never formed the bulk of droppings.

Fungus Unidentified

One Barred Bandicoot scat contained the Lamellae part of a mushroom type fungus covered with many spores. Unidentified large, brown fungal spores appeared in Brown Bandicoot scats associated with the Gasteromycete fungi encountered. These two unidentified fungi were grouped together for subsequent analysis.

Fungus Gasteromycete

Underground puffball mushroom of the Class Gasteromycete was readily detected in faecal pellets by the tough wall structure of the puffball. Furthermore, microscopic analysis revealed two types of spores: (1) spores similar to a *Hymenogaster* type spore and (2) spores similar to a *Rhizophogon* type puffball. Both types were found in *I. obesulus*, only the latter in *P. gunnii*. Occasionally spores solely were detected in the absence of the walls.

Fungus Zygomycete

The Endotrophic mycorrhizas formerly grouped as *Endogone* (Deacon 1980) were detected in the faeces of both bandicoot species. Both the large spores and penetrating hyphae of at least one species, which ramify between plant root cells and the soil were located in faeces.

Clover Leaves

Clover leaves were detected in faeces from both species of bandicoot and appeared to be relatively unaffected by the bandicoot digestive processes.

Nodules?

A large number of scats from *P. gunnii* and *I. obesulus* contained what appeared to be root nodules of white clover (*Trifolium repens*). Although I was unable to confirm the identification, root nodules extracted from Clover plants were very similar in appearance.

Moss

Three species of moss were detected in the faeces of Brown Bandicoots while only one of these was detected in the Barred Bandicoot. The dominant moss found in both species whose faeces were collected from the wet sclerophyll and golf course study site was *Lembophyllum divulsum*. Brown Bandicoot scats collected from the heath frequently contained *Campylopus* sp. while one scat contained *Camptochaete arbuscula*.

Dicot

Dicot consisted of unidentified leaf pieces and *Acacia dealbata* (Silver wattle) phyllodes were occasionally consumed on the two wet sclerophyll forest study sites.

Monocot

This category contained the grasses often detected in bandicoot faeces. The dominant grass consumed over the three study sites was Couch grass (*Cynodon dactylon*). The Blue Tussock grass (*Poa poiformis*) and an unidentified grass species was important on study sites two and three, and a *Poa* sp. (possibly *Poa annua*) was of considerable importance on study site one.

Seeds

A list of the seed species recovered from the scats of *I. obesulus* and *P. gunnii* together with the percentage of the total number of scats containing each seed species is shown in Table 7.1.3.b.1.

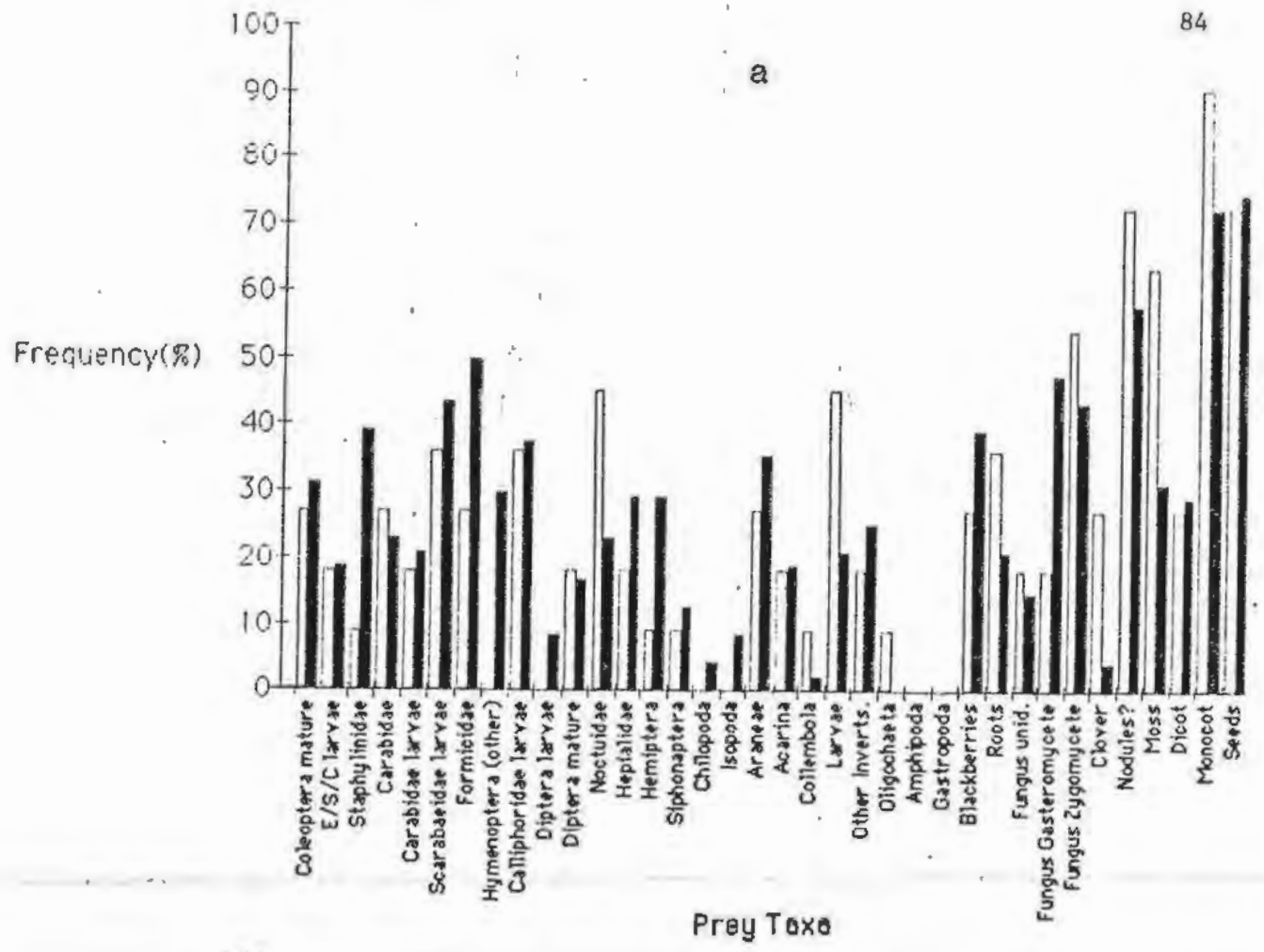
A variety of seeds were detected in bandicoot scats, and in similar frequencies. However, seeds never existed in substantial quantities except in winter for the golf course site when unquantifiable numbers of the seeds of Unidentified Monocot A occurred in Brown Bandicoot scats.

7.1.4 Results - Total Diet

The frequency distribution of the number of samples containing various prey taxa summed over all seasons and habitats is illustrated in Figure 7.1.4.1 for *Isoodon obesulus* and *Perameles gunnii*, and for soil samples and pitfall traps. The seasonal and total categories of the diet for *I. obesulus* and *P. gunnii* is tabulated in Table 7.1.4.1. Taxonomic categories are presented with invertebrate groups first and plant groups second. A Kolmogorov-Smirnov two-sample test (Siegel 1956) shows no significant difference between distribution of the number of samples containing the various prey taxa for each of the bandicoot species

TABLE 7.1.3.b.1 Frequency (percentage) of the total number of scats (in brackets) containing various seed species

Seed Species	*I. obesulus* (48)	*P. gunnii* (11)
Agrostis capillaris	43.75%	45.45%
Agrostis sp.	4.17%	-
Anthoxanthum odoratum	2.09%	-
Danthonia caespitosa	2.09%	-
Deyeuxia densa	10.42%	18.18%
Gnaphalium sp.	2.09%	9.1%
Holcus lanatus	2.09%	9.1%
Hordium vulgare	4.17%	-
Hypochaeris radicata	10.42%	-
Lolium perenae	4.17%	9.1%
Phalaris minor	8.34%	9.1%
Plantago sp.	4.17%	-
Schoenus apogon	4.17%	-
Trifolium dubium	2.09%	9.1%
T. repens	14.58%	18.18%
T. subterraneum	2.09%	9.1%
Trifolium sp.	8.33%	-
Unidentified	16.67%	-
Unidentified Monocot A	14.58%	-


a
Frequency(%)
100
90
80
70
60
50
40
30
20
10
0
Coleoptera mature
E/S/C larvae
Staphylinidae
Carabidae
Carabidae larvae
Scarabaeidae larvae
Formicidae
Hymenoptera (other)
Calliphoridae larvae
Diptera larvae
Diptera mature
Noctuidae
Heptialidae
Hemiptera
Siphonaptera
Chilopoda
Isopoda
Araneae
Acarina
Collembola
Larvae
Other Inverts.
Oligochaeta
Amphipoda
Gastropoda
Blackberries
Roots
Fungus unid.
Fungus Gasteromycete
Fungus Zygomycete
Clover
Nodules?
Moss
Dicot
Monocot
Seeds
Prey Taxa

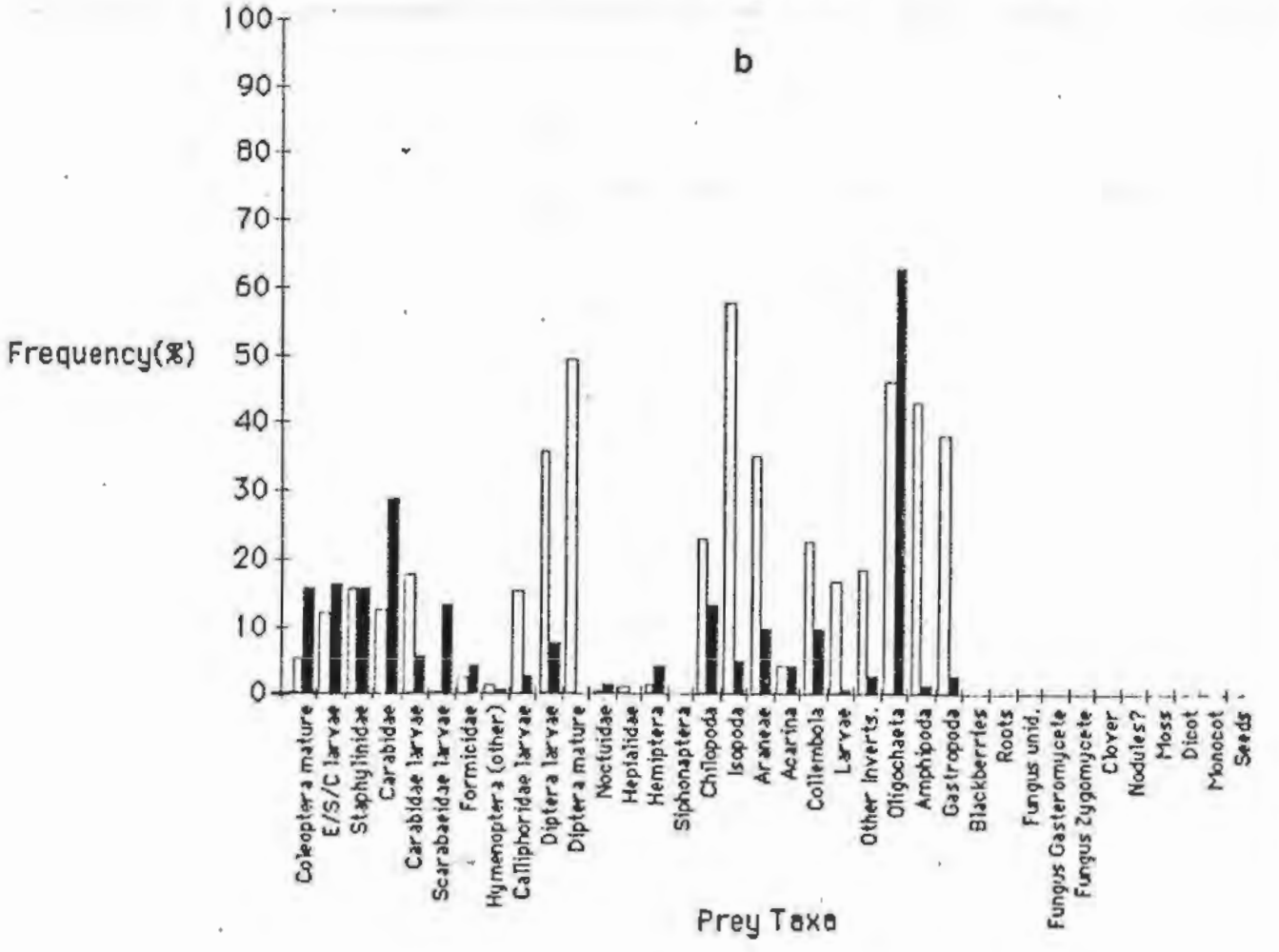

b
Frequency(%)
100
90
80
70
60
50
40
30
20
10
0
Coleoptera mature
E/S/C larvae
Staphylinidae
Carabidae
Carabidae larvae
Scarabaeidae larvae
Formicidae
Hymenoptera (other)
Calliphoridae larvae
Diptera larvae
Diptera mature
Noctuidae
Heptialidae
Hemiptera
Siphonaptera
Chilopoda
Isopoda
Araneae
Acarina
Collembola
Larvae
Other Inverts.
Oligochaeta
Amphipoda
Gastropoda
Blackberries
Roots
Fungus unid.
Fungus Gasteromycete
Fungus Zygomycete
Clover
Nodules?
Moss
Dicot
Monocot
Seeds
Prey Taxa

TABLE 7.1.4.1 Seasonal and total diet categories of the diet for *I. obesulus* and *P. gunnii*. Values are the number of scats containing that prey category for summer, winter, spring and total diet. Within parentheses are the frequency (percentage) of the total number of scats containing that prey item for summer, winter, spring and total diets. For an explanation of the categories, see text.

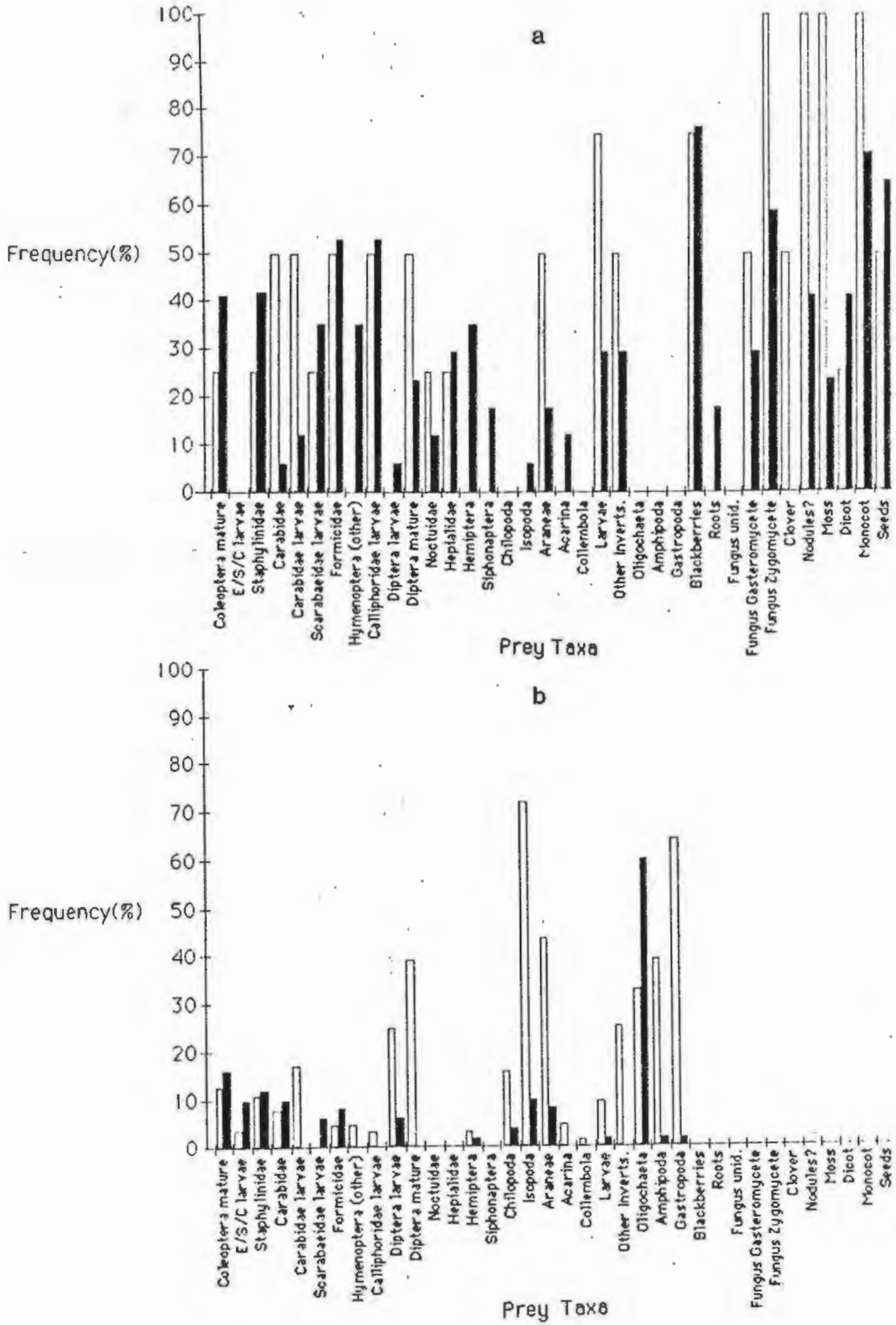
Category	*I. obesulus*				*P. gunnii*			
	Autumn	Winter	Spring	Total	Autumn	Winter	Spring	Total
Coleoptera mature	7(41.2)	7(41.2)	1(7.2)	15(31.3)	1(25.0)	0(0)	2(40.0)	3(27.3)
E/S/C larvae	0(0)	2(11.8)	7(50.0)	9(18.8)	0(0)	0(0)	2(40.0)	2(18.2)
Staphylinidae	7(41.2)	5(29.4)	7(50.0)	19(39.6)	1(25.0)	0(0)	0(0)	1(9.1)
Carabidae	1(5.9)	5(29.4)	5(35.7)	11(22.9)	2(50.0)	0(0)	1(20.0)	3(27.3)
Carabidae larvae	2(11.8)	8(47.1)	1(7.1)	10(20.8)	2(50.0)	0(0)	0(0)	2(18.2)
Scarabaeidae larvae	6(35.3)	11(64.7)	4(28.6)	21(43.8)	1(25.0)	1(50.0)	2(40.0)	4(36.4)
Formicidae	9(52.9)	10(58.8)	5(35.7)	24(50.0)	2(50.0)	0(0)	1(20.0)	3(27.3)
Hymenoptera (other)	6(35.3)	5(29.4)	3(21.4)	14(29.2)	0(0)	0(0)	0(0)	0(0)
Calliphoridae larvae	9(52.9)	5(29.4)	4(28.6)	18(37.5)	2(50.0)	1(50.0)	1(20.0)	4(36.4)
Diptera larvae	1(5.9)	3(17.7)	0(0)	4(8.3)	0(0)	0(0)	0(0)	0(0)
Diptera mature	4(23.5)	1(5.9)	3(21.4)	8(16.7)	2(50.0)	0(0)	0(0)	2(18.2)
Noctuidae	2(11.8)	6(35.3)	3(21.4)	11(22.9)	1(25.0)	1(50.0)	3(60.0)	5(45.5)
Hepialidae	5(29.4)	0(0)	9(64.3)	14(29.2)	1(25.0)	0(0)	1(20.0)	2(18.2)
Hemiptera	6(35.3)	3(17.7)	5(35.7)	14(29.2)	0(0)	0(0)	1(20.0)	1(9.1)
Siphonaptera	3(17.7)	2(11.8)	1(7.1)	6(12.5)	0(0)	0(0)	1(20.0)	1(9.1)
Chilopoda	0(0)	2(11.8)	0(0)	2(4.2)	0(0)	0(0)	0(0)	0(0)
Isopoda	1(5.9)	2(11.8)	1(7.1)	4(8.4)	0(0)	0(0)	0(0)	0(0)
Araneae	3(17.7)	4(23.5)	10(71.4)	17(35.4)	2(50.0)	0(0)	1(20.0)	3(27.3)
Acarina	2(11.8)	2(11.8)	5(35.7)	9(18.8)	0(0)	0(0)	2(40.0)	2(18.2)
Collembola	0(0)	1(5.9)	0(0)	1(2.1)	0(0)	1(50.0)	0(0)	1(9.1)
Larvae	5(29.4)	2(11.8)	3(21.4)	10(20.8)	3(75.0)	0(0)	2(40.0)	5(45.5)
Other invertebrates	5(29.4)	5(29.4)	2(14.3)	12(25.0)	2(50.0)	0(0)	0(0)	2(18.2)
Oligochaeta	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)	1(20.0)	1(9.1)
Amphipoda	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)
Gastropoda	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)
Blackberries	13(76.5)	5(29.4)	1(7.1)	19(39.6)	3(75.0)	0(0)	0(0)	3(27.3)
Roots	3(17.7)	6(35.3)	1(7.1)	10(20.8)	0(0)	1(50.0)	3(60.0)	4(36.4)
Fungus unidentified	0(0)	2(11.8)	5(35.7)	7(14.6)	0(0)	1(50.0)	1(20.0)	2(18.2)
Fungus Gasteromycete	5(29.4)	11(64.7)	7(50.0)	23(47.9)	2(50.0)	0(0)	0(0)	2(18.2)
Fungus Zygomycete	10(58.8)	9(52.9)	2(14.3)	21(43.8)	4(100.0)	1(50.0)	1(20.0)	6(54.5)
Clover	0(0)	0(0)	2(14.3)	2(4.2)	2(50.0)	0(0)	1(20.0)	3(27.3)
Nodules?	7(41.2)	12(70.6)	9(64.3)	28(58.3)	4(100.0)	2(100.0)	2(40.0)	8(72.7)
Moss	4(23.5)	7(41.2)	5(35.7)	15(31.3)	4(100.0)	1(50.0)	2(40.0)	7(64.6)
Dicot	7(41.2)	3(17.7)	4(28.6)	14(29.2)	1(25.0)	1(50.0)	1(20.0)	3(27.3)
Monocot	12(70.6)	12(70.6)	11(78.6)	35(72.9)	4(100.0)	1(50.0)	5(100.0)	10(90.1)
Seeds	11(64.7)	15(88.2)	10(71.4)	36(75.0)	2(50.0)	2(100.0)	4(80.0)	8(72.7)
Number of Samples	17	17	14	48	4	2	5	11

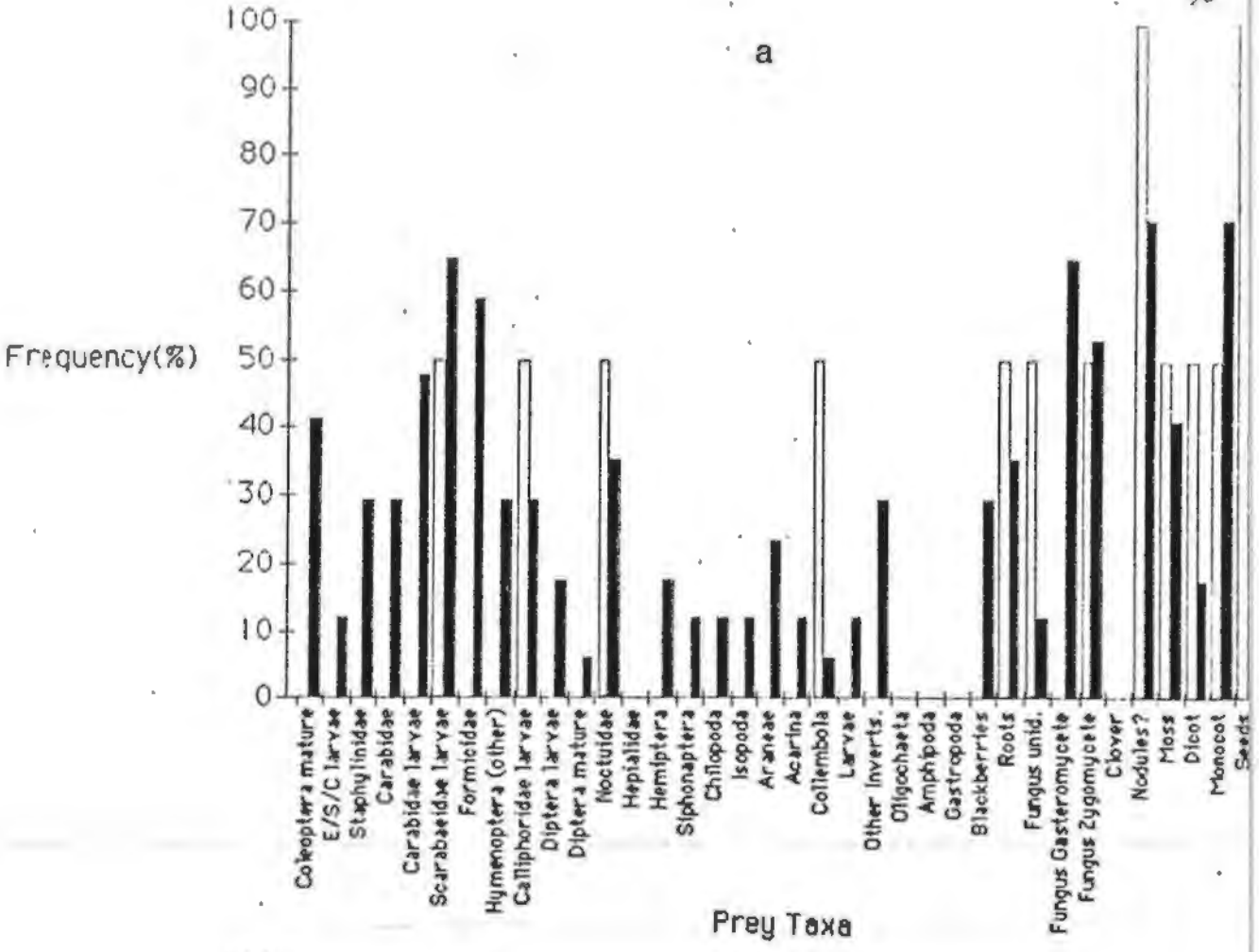
($D=0.139$, $n_1=464$, $n_2=103$, $0.05<P<0.01$). Furthermore, another qualitative comparison, the Spearman rank correlation (Siegel 1956), depicts that the rank order correlation of the two predators' distributions is positively correlated and not significantly different ($r_s=+0.591$, $n=36$, $P<0.001$). Hence the two prey samples appear to have been drawn from the same prey population. When compared quantitatively, by considering each dietary category separately, two show significant differences. These were the higher incidence of faecal pellets for *I. obesulus* containing Hymenoptera (29.2% (14 of 48) v. 0% (0 of 11), $X^2=4.09$, d.f.=1, $0.01<P<0.05$) and the greater proportion of *P. gunnii* scats containing clover (27.3% (3 of 11) v. 4.2% (2 of 48), $X^2=4.24$, d.f.=1, $0.01<P<0.05$). The only dietary category which approaches a significant difference is the higher frequency of *I. obesulus* faeces containing Rove Beetles (Staphylinidae) (39.6% (19 of 48) v. 9.1% (1 of 11), but this is not significantly different ($X^2=3.10$, d.f.=1, $0.05<P<0.1$).

7.1.5 Results - Seasonal Diet

Frequency distributions of the seasonal number of scats, soil samples and pitfall traps containing the various prey categories are presented for autumn, winter and spring in Figs. 7.1.5.1-3, respectively. Qualitative tests were employed on seasonal distributions in diet utilising the same Kolmogorov-Smirnov two-sample tests used previously. Data were pooled for the autumn and winter samples for *Perameles gunnii* because of the small winter sample.

The Kolmogorov-Smirnov test illustrates no significant difference between the autumn-winter and spring distributions for *P. gunnii* ($D=0.11$, $n_1=62$, $n_2=41$, $P>0.1$). The test also demonstrates no significant difference exists between the distributions of scats containing the various prey taxa for *Isoodon obesulus* for autumn and winter ($D=0.091$, $n_1=156$, $n_2=173$, $P>0.1$), autumn and spring ($D=0.113$, $n_1=156$, $n_2=135$, $P>0.1$), and the winter and spring ($D=0.100$, $n_1=173$, $n_2=135$, $P>0.1$) samples.


a
b
Frequency(%)
Prey Taxa
Coleoptera mature
E/S/C larvae
Staphylinidae
Carabidae
Carabidae larvae
Scarabaeidae larvae
Formicidae
Hymenoptera (other)
Calliphoridae larvae
Diptera larvae
Diptera mature
Noctuidae
Heptiidae
Hemiptera
Siphonaptera
Chilopoda
Isopoda
Araneae
Acarina
Collembola
Larvae
Other Inverts.
Oligochaeta
Amphipoda
Gastropoda
Blackberries
Roots
Fungus unid.
Fungus Gasteromycete
Fungus Zygomycete
Clover
Nodules?
Moss
Dicot
Monocot
Seeds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Frequency(%)
100
90
80
70
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30
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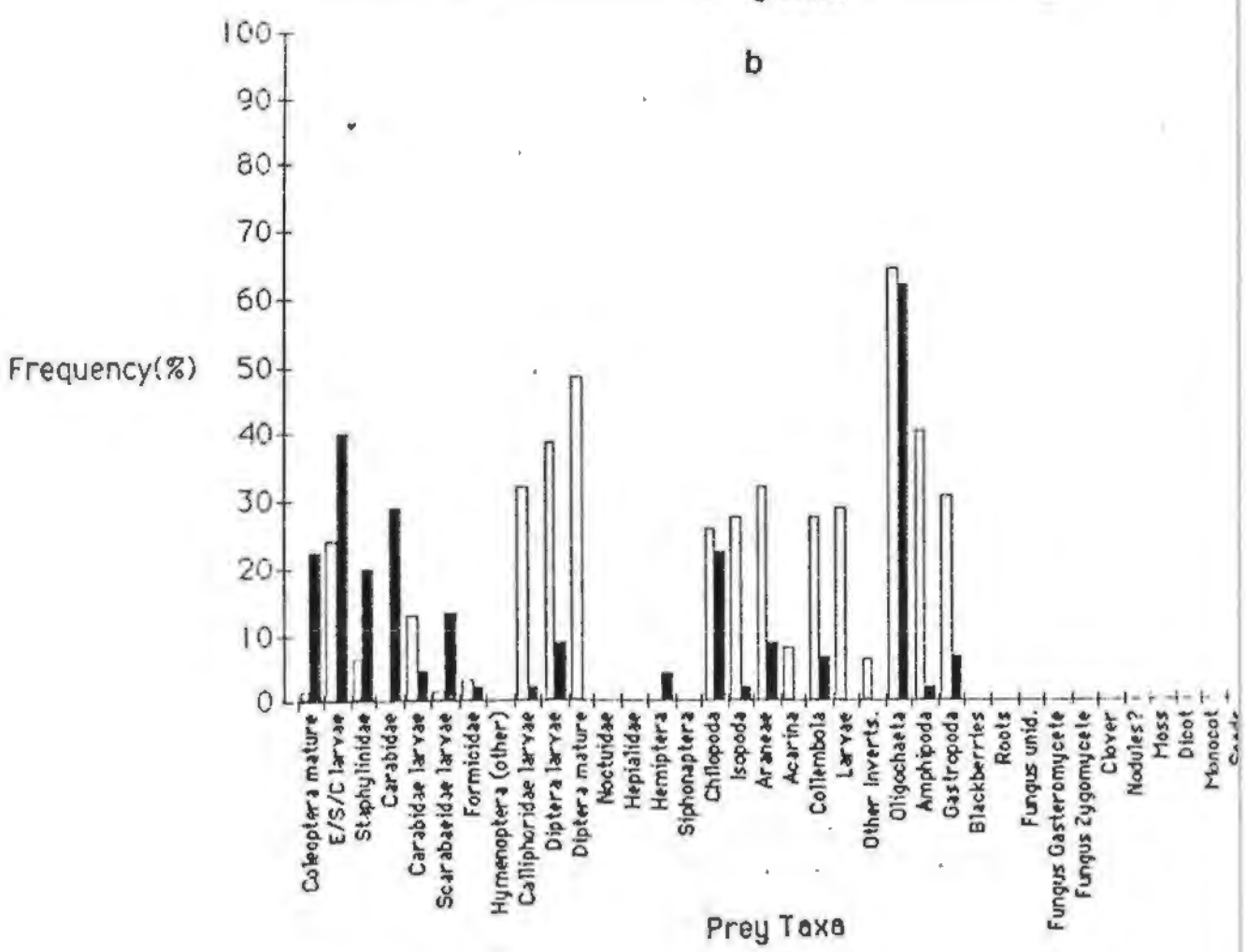
10
0
Coleoptera mature
E/S/C larvae
Staphylinidae
Carabidae
Carabidae larvae
Scarabaeidae larvae
Formicidae
Hymenoptera (other)
Calliphoridae larvae
Diptera larvae
Diptera mature
Noctuidae
Hepialidae
Hemiptera
Siphonaptera
Chilopoda
Isopoda
Araneae
Acarina
Collembola
Larvae
Other inverts.
Oligochaeta
Amphipoda
Gastropoda
Blackberries
Roots
Fungus unid.
Fungus Gasteromycete
Fungus Zygomycete
Clover
Nodules?
Moss
Dicot
Monocot
Seeds
Prey Taxa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Carabidae
Carabidae larvae
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Hepialidae
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Siphonaptera
Chilopoda
Isopoda
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Acarina
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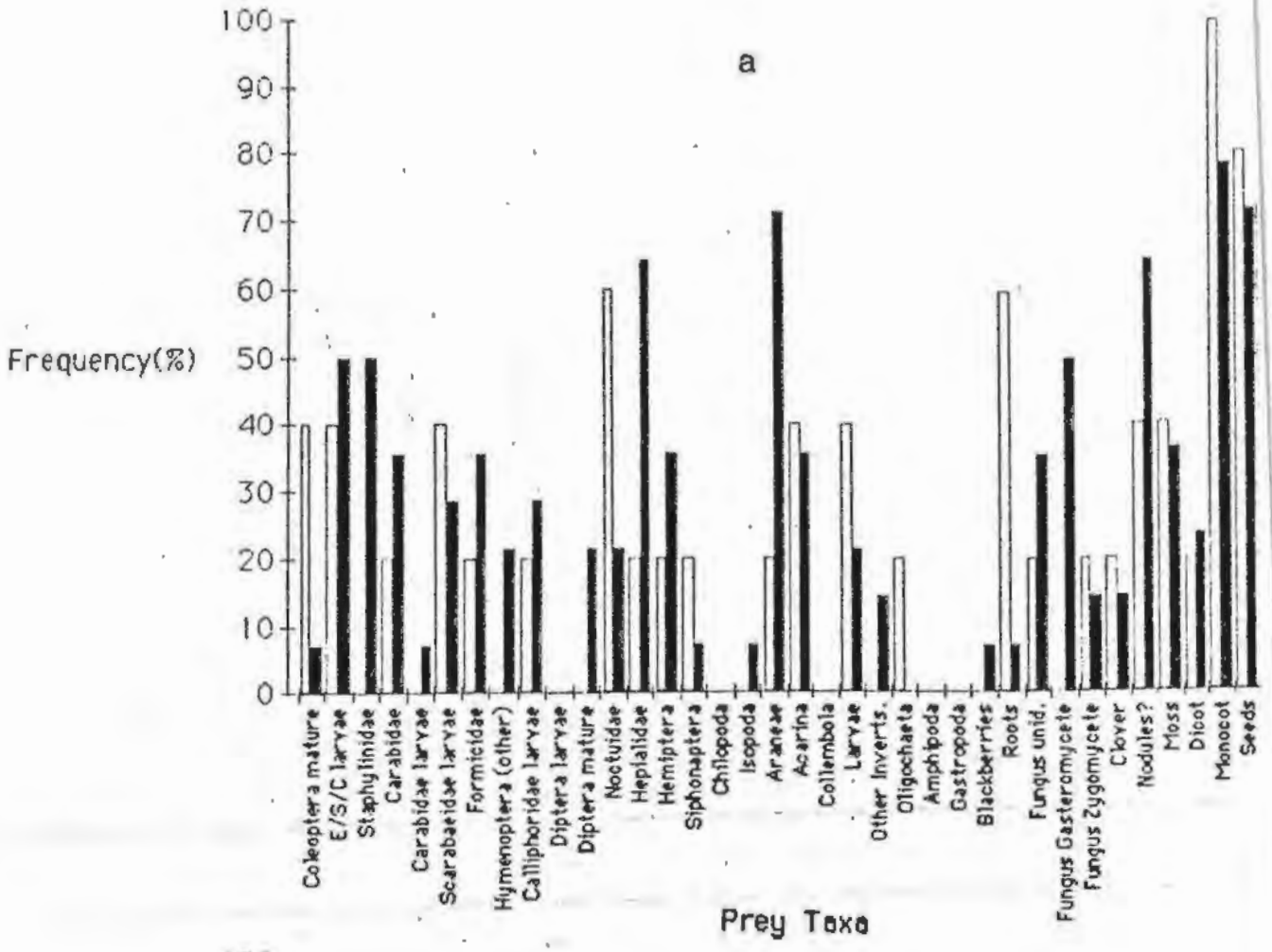
Prey Taxa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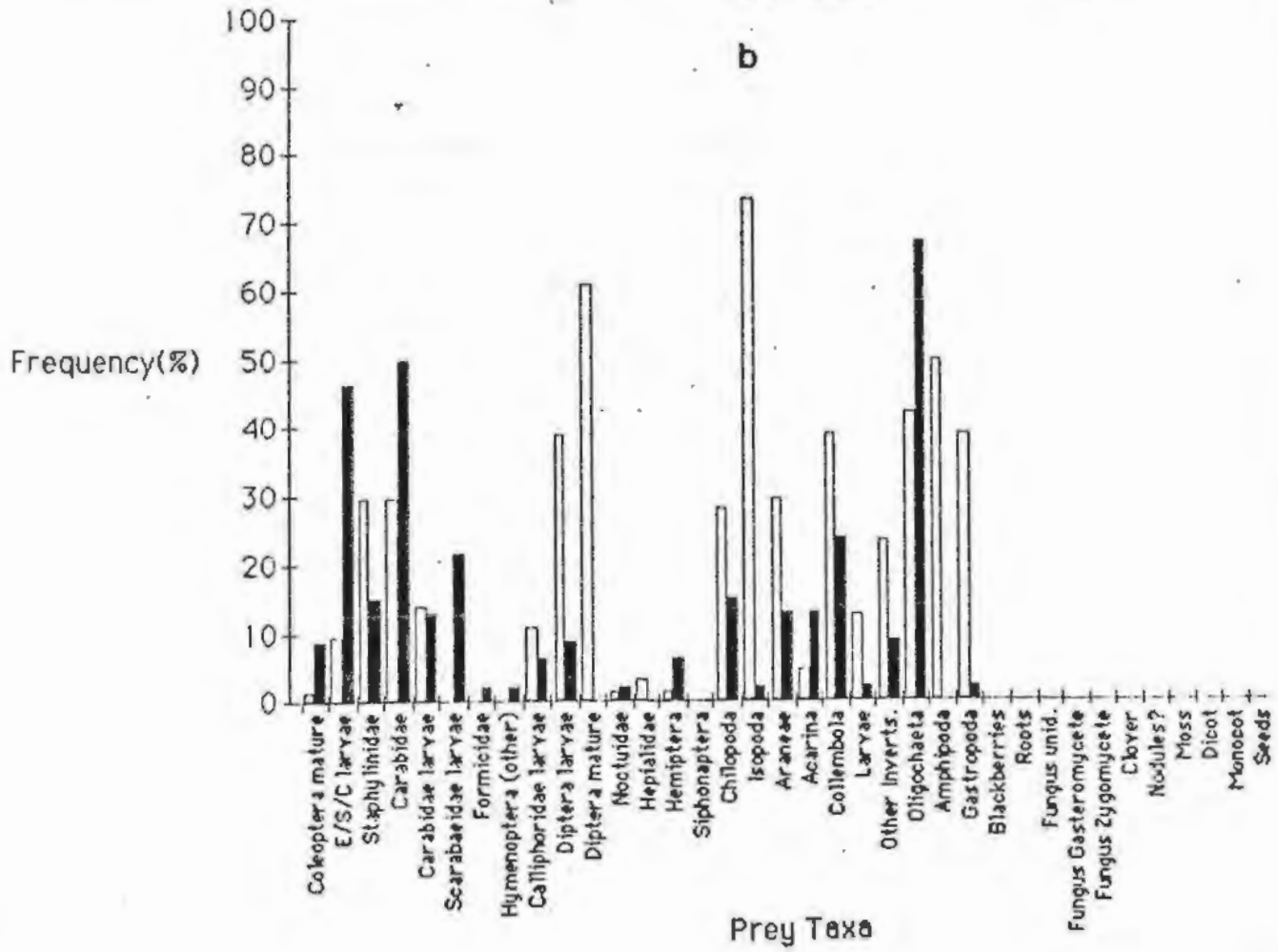
Coleoptera mature
E/S/C larvae
Staphylinidae
Carabidae
Carabidae larvae
Scarabaeidae larvae
Formicidae
Hymenoptera (other)
Calliphoridae larvae
Diptera larvae
Diptera mature
Noctuidae
Hepialidae
Hemiptera
Siphonaptera
Chilopoda
Isopoda
Araneae
Acarina
Collembola
Larvae
Other Inverts.
Oligochaeta
Amphipoda
Gastropoda
Blackberries
Roots
Fungus unid.
Fungus Gasteromycete
Fungus Zygomycete
Clover
Nodules?
Moss
Dicot
Monocot
Seeds
Prey Taxa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Coleoptera mature
E/S/C larvae
Staphylinidae
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Carabidae larvae
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Diptera larvae
Diptera mature
Noctuidae
Hepialidae
Hemiptera
Siphonaptera
Chilopoda
Isopoda
Araneae
Acarina
Collembola
Larvae
Other Inverts.
Oligochaeta
Amphipoda
Gastropoda
Blackberries
Roots
Fungus unid.
Fungus Gasteromycete
Fungus Zygomycete
Clover
Nodules?
Moss
Dicot
Monocot
Seeds
Prey Taxa

Chi-square values for intraspecific differences between seasons for individual diet categories of *I. obesulus* are presented in Table 7.1.5.1. Only significant differences are presented. In addition, only two further diet categories approached significant seasonal differences: Ground Beetles (Carabidae) were found in a smaller proportion of scats in autumn than other seasons (X^2=3.764, d.f.=1, 0.05<P<0.1); Centipedes (Chilopoda) were detected in a higher incidence of faecal samples in winter (X^2=3.379, d.f.=1, 0.05<P<0.1). However, in both instances seasonal differences were not significant.

A higher incidence of scats containing E/S/C larvae, Araneae, unidentified fungus and Clover were detected in spring than other seasons while the reverse was true for Coleopteran beetles and unidentified fungus (also in a lesser frequency in autumn). Scats containing Carabidae larvae were more frequent in winter whereas scats with Hepialidae and Blackberries were less frequent in winter and more frequent in autumn respectively. The number of samples for *P. gunnii* was considered to be too small to test for Chi-square comparisons between seasons.

The same seasonal invertebrate patterns were sought in soil samples and pitfall traps by employing the same Chi-square tests where the data showed similar seasonal trends. Soil sampling and pitfall trapping data revealed that although two of the five dietary categories (mature Coleoptera and E/S/C larvae) approached the same seasonal patterns as represented in the diet, all five were not significant. The trend observed in the seasonal diet of *I. obesulus* with Carabidae beetles and centipedes was reflected by a significant difference in a similar seasonal pattern in soil samples for Carabidae (X^2=10.00, d.f.=1, 0.001<P<0.005), and a trend towards a significant difference for centipedes in soil samples (X^2=3.48, d.f.=1, 0.05<P<0.1).

7.1.6 Results - Prey Availability

The frequency distribution of the pitfall traps and soil samples containing the various prey taxa is illustrated for the total diet in Fig. 7.1.4.1, and for seasonal diets in Figs. 7.1.5.1-3. These frequency distributions are employed as the 'expected' prey distributions for which dietary prey categories are directly compared, expressing the values as the number of soil samples or pitfall traps containing the various prey taxa. By the Kolmogorov-Smirnov two-sample tests, a significant discrepancy

TABLE 7.1.5.1 Chi-square values for significant seasonal differences for the frequency of Brown Bandicoot scats containing the various prey taxa. Chi-square values for significant seasonal differences for the frequency of soil samples and pitfall traps containing the same seasonal pattern

Prey Taxa	Seasonal Difference	Chi-square Value for Diet		Chi-square value for Soils (*) or Pitfall (**)	
Coleoptera mature	Spring<autumn, winter	4.20	P<0.05	2.940**	P<0.1 trend
E/S/C larvae	Spring>autumn, winter	9.05	P<0.005	3.581*	P<0.1 trend
Carabidae larvae	Winter>autumn, spring	6.31	P<0.025		n.s.
Hepialidae	Winter<autumn, spring	8.22	P<0.005		n.s.
Araneae	Spring>autumn, winter	6.71	P<0.025		n.s.
Blackberries	Autumn>winter, spring	8.69	P<0.005		-
Fungus Zygomycete	Spring<autumn, winter	4.37	P<0.05		-
Fungus unidentified	Spring>autumn, winter	5.38	P<0.025		-
" "	Autumn<winter, spring	5.54	P<0.025		-
Clover	Spring>autumn, winter	4.05	P<0.05		-

n.s. = not significant
- not measured by soil sampling or pitfall trap analysis

exists between the frequency distribution of prey taxa occurring in the total diet of *Isoodon obesulus* and soil samples ($D=0.292$, $n_1=254$, $n_2=325$, $P<0.001$) and pitfall traps ($D=0.425$, $n_1=254$, $n_2=908$, $P<0.001$). The frequency distribution of prey taxa occurring in the total diet of *P. gunnii* also departed significantly from that in soil samples ($D=0.292$, $n_1=50$, $n_2=325$, $P<0.005$) and pitfall traps ($D=0.361$, $n_1=50$, $n_2=908$, $P<0.001$).

Kolmogorov-Smirnov tests were employed to test separately for differences between seasons and between habitats for *I. obesulus*. The frequency distribution of the number of faecal pellets containing prey categories differed significantly from the distribution of soil samples and pitfall traps for autumn (soil samples; $D=0.405$, $n_1=84$, $n_2=79$, $P<0.001$: pitfall traps, $D=0.504$, $n_1=74$, $n_2=284$, $P<0.001$), winter (soil samples; $D=0.291$, $n_1=91$, $n_2=116$, $P<0.001$: pitfall traps; $D=0.474$, $n_1=91$, $n_2=286$, $P<0.001$) and spring (soil samples; $D=0.249$, $n_1=80$, $n_2=151$, $P<0.001$: pitfall traps; $D=0.341$, $n_1=80$, $n_2=336$, $P<0.001$).

Habitat differences between the frequency distributions of prey taxa in the diet of *I. obesulus* and pitfall traps were significant for the wet sclerophyll forest-open pasture ($D=0.447$, $n_1=74$, $n_2=403$, $P<0.001$), regenerating wet sclerophyll forest-golf course ($D=0.495$, $n_1=60$, $n_2=255$, $P<0.001$) and regenerating wet heath ($D=0.425$, $n_2=117$, $n_2=277$, $P<0.001$) study sites. Discrepancies between the diet and soil samples were significant for the wet sclerophyll forest ($D=0.446$, $n_1=74$, $n_2=142$, $P<0.001$), the heath ($D=0.189$, $n_1=117$, $n_2=127$, $0.025<P<0.05$), but not for the regenerating wet sclerophyll forest ($D=0.204$, $n_1=60$, $n_2=75$, $0.05<P<0.1$). For the only habitat test considered possible because of the small samples collected for *Perameles gunnii*, the prey distribution for the diet did not depart significantly from that in soil samples ($D=0.221$, $n_1=47$, $n_2=75$, $0.1<P<0.5$), but did in pitfall traps ($D=0.325$, $n_1=47$, $n_2=255$, $P<0.001$) on the regenerating wet sclerophyll forest-golf course site.

Table 7.1.6.1 shows the seasonal and total diet Chi-square values for differences between the frequency of individual prey categories in faecal pellets, and soil samples or pitfall traps for *I. obesulus*. Only total differences are presented for *P. gunnii* because of the small seasonal diet samples collected for this species. A large number of

TABLE 7.1.6.1 Chi-square values comparing the frequency of faecal pellets, soil samples and pitfall traps containing the various prey taxa for seasonal and total diets for *I. obesulus* and for total diet for *P. gunnii* only.

Prey Taxa	*I. obesulus*								*P. gunnii*	
	Autumn		Winter		Spring		Total		Total	
	Soil Samples	Pitfall Traps	Soil Samples	Pitfall Traps	Soil Samples	Pitfall Traps	Soil Samples	Pitfall Traps	Soil Samples	Pitfall Traps
Coleoptera mature	+4.50*	+5.16*	+1.38	+18.46***	-0.41	+0.87	+6.67**	+23.22***	+0.40	+5.16*
E/S/C larvae	-2.52	-2.70	-3.50	-1.37	+0.07	+9.97**	+0.09	+1.04	+0.08	+0.06
Staphylinidae	+4.93*	+6.20*	+0.39	+5.19*	+4.86*	+1.09	+8.97**	+9.88**	-0.82	-0.85
Carabidae	-0.69	-0.47	+0.06	+15.87***	-0.68	+0.08	-0.63	+2.38	-0.15	+0.86
Carabidae larvae	+4.61*	-0.56	+12.81***	+6.84**	-0.79	-0.95	+7.92**	+0.12	+1.18	+0.12
Scarabaeidae larvae	+7.20**	+20.08***	+11.10***	+32.69***	+0.16	+15.12***	+14.87***	+74.69***	+2.39	+41.85***
Formicidae	+12.16***	+19.35***	+21.02***	+25.17***	+10.51**	+19.63***	+45.87***	+68.32***	+6.21*	+10.97***
Hymenoptera (other)	+13.89***	+9.89**	+11.86***	+15.87***	+4.75*	+10.74**	+35.75***	+38.92***	-4.79*	-2.73
Calliphoridae larvae	+24.75***	+22.57***	+8.34**	-0.15	+3.68	+2.09	+35.51***	+9.00**	+27.49***	+1.82
Diptera larvae	+0.34	-3.72	+0.67	-2.14	-2.27	-6.31*	+0.08	-10.08**	-2.12	-5.00*
Diptera mature	+10.14**	-1.21	+2.26	-6.81**	+8.04**	-3.83	+21.69***	-10.07**	+15.64***	-2.76
Noctuidae	+4.59*	+2.70	+18.41***	+19.47***	+4.75*	+6.76**	+22.65***	+35.95***	+35.29***	+71.66***
Hepialidae	+13.04***	+15.53***	-	-	+27.44***	+27.85***	+39.22***	+42.57***	+15.63***	+8.82**
Hemiptera	+12.11***	+12.45***	+2.19	+8.78**	+5.85*	+14.86***	+19.88***	+38.53***	+0.15	+0.79
Siphonaptera	+7.33**	+9.03***	+4.31*	+5.45*	+2.41	+4.70*	+16.35***	+21.52***	+4.56*	+5.82*
Chilopoda	-2.00	-3.52	-1.05	-1.59	-3.02	-4.81*	-3.28	-7.19**	-2.60	-3.60
Isopoda	-1.04	-10.79**	+1.83	-1.80	+0.69	-8.94**	+0.52	-22.40***	-2.00	-7.35**
Araneae	+0.86	-2.83	+1.69	-0.56	+12.62***	+4.72*	+13.46***	-0.01	+1.64	-0.46
Acarina	+4.60*	+0.31	+4.31*	+0.19	+2.47	+9.08**	+8.62**	+6.91**	+1.99	+1.12
Collembola	-	-2.51	-0.39	-3.33	-4.18*	-6.31*	-3.38	-9.44**	-0.33	-1.53
Larvae	+8.89**	+3.26	+4.31*	-4.46*	+4.75*	+0.40	+23.31***	+0.26	+42.77***	+3.37
Other invertebrates	+13.04***	+0.07	+11.82***	+5.19**	+0.27	-0.81	+27.5***	+0.69	+3.43	-0.14
Oligochaeta	-10.91***	-6.39*	-11.23***	-11.73***	-10.17**	-6.76**	-30.96***	-22.61***	-5.85*	-6.57*
Amphipoda	-2.32	-7.42**	-2.26	-7.65**	-	-7.84**	-2.00	-21.50***	-2.93	-6.17*
Gastropoda	-2.32	-11.66***	-2.18	-6.00**	-2.41	-3.75	-2.35	-19.22***	-2.17	-5.23*

+ Frequency of faecal pellets greater than that of soil samples or pitfall traps
- Frequency of faecal pellets lesser than that of soil samples or pitfall traps
* P<0.05; ** P<0.01; *** P<0.001

significant differences are apparent for both species; however, the total diet for *P. gunnii* appears to contain fewer discrepancies than that for *I. obesulus*. Some prey categories show consistent seasonal differences for both soil samples and pitfall traps and are manifested in the total diet e.g. Formicidae, other Hymenoptera and Oligochaeta for *I. obesulus*. Other taxa e.g. Scarabaeidae larvae, Noctuidae, Hemiptera, Siphonaptera, show a significantly greater number of scats containing the item in all seasons than soil samples and pitfall traps excepting one seasonal and prey sampling component. Categories such as E/S/C larvae, Carabidae beetles, Dipteran larvae, Chilopoda, show only one significant seasonal difference for either soil samples or pitfall traps for *I. obesulus*. The total diet for *P. gunnii* appears to reflect a mixture of soil samples and pitfall traps with all categories except Formicidae, Noctuidae, Hepialidae, Siphonaptera and Oligochaeta possessing either no significant difference or only one significant difference for either soil samples or pitfall traps.

7.1.7 Results - Habitat (*Isoodon obesulus*)

Since only one faecal pellet was collected for *Perameles gunnii* on any one site excluding the regenerating wet sclerophyll forest-golf course study site (where 10 of the 11 samples were collected), qualitative and quantitative tests for differences between habitat (summed for all seasons) were only performed for *Isoodon obesulus*. The frequency distribution of the number of faecal samples collected for *I. obesulus* containing the various prey categories is illustrated in Fig. 7.1.7.1. The Kolmogorov-Smirnov two-sample tests depict no significant difference between the frequency distributions for the wet sclerophyll forest and regenerating forest ($D=0.106$, $n_1=139$, $n_2=129$, $P>0.1$), or for the wet sclerophyll forest and the heath ($D=0.093$, $n_1=139$, $n_1=193$, $P>0.1$). However, a significant discrepancy arose for the wet heath and regenerating forest ($D=0.182$, $n_1=129$, $n_2=193$, $0.01<P<0.025$).

Eleven of the dietary categories showed differences between habitat for *I. obesulus* (Table 7.1.7.1). Significantly fewer scats from the regenerating wet sclerophyll forest-golf course site contained Carabidae beetles, Hepialidae, Araneae, and Roots, while a significantly higher incidence of scats from the site contained Siphonaptera and Moss. A significantly lower incidence of samples from the wet sclerophyll forest contained Carabidae larvae, Noctuidae and roots relative to the remaining two sites, the reverse being true for clover. A significantly greater

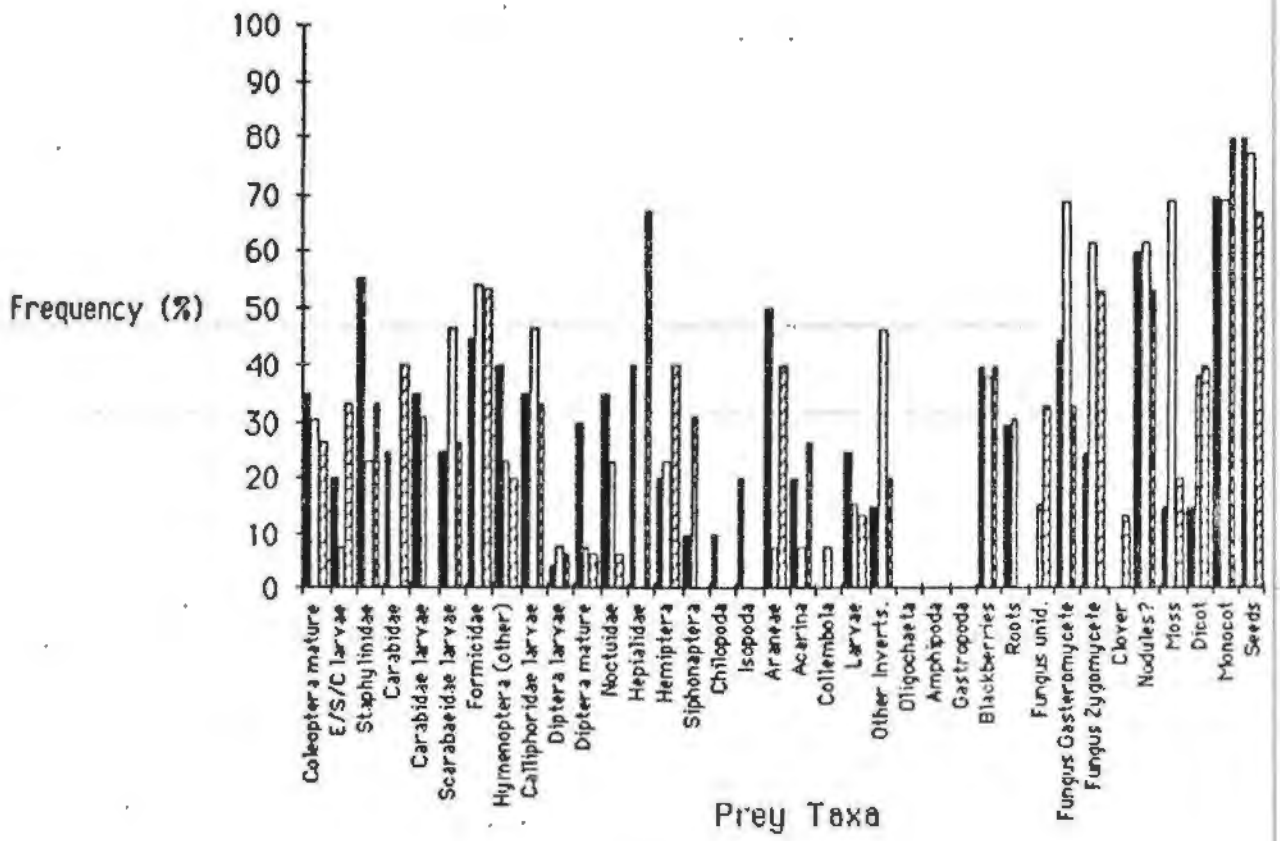

FIG. 7.1.7.1 Frequency distribution of the number of faecal samples collected for *I. obesulus* containing the various prey categories on regenerating wet heath (solid bars), regenerating wet sclerophyll forest-golf course fairways (open bars) and wet sclerophyll forest-open pasture (hatched bars) study sites.

TABLE 7.1.7.1 Chi-square values showing significant differences only between habitats for the number of faecal pellets collected for *I. obesulus* containing the various prey taxa (W.S.F. = wet sclerophyll forest)

Prey Category	Habitat Difference	Chi-square Value	
Carabidae	Regenerating forest < W.S.F., Heath	4.83	0.025<P<0.05
Carabidae larvae	W.S.F. < Regenerating forest, Heath	5.66	0.01<P<0.025
Noctuidae	W.S.F. < Regenerating forest, Heath	5.91	0.01<P<0.025
Hepialidae	Regenerating forest < W.S.F., Heath	6.17	0.01<P<0.025
Siphonaptera	Regenerating forest > W.S.F., Heath	4.05	0.025<P<0.05
Isopoda	Heath > W.S.F., Regenerating Forest	5.45	0.01<P<0.025
Araneae	Regenerating forest < W.S.F., Heath	4.44	0.025<P<0.05
Moss	Regenerating forest > W.S.F., Heath	7.56	0.005<P<0.01
Clover	W.S.F. < Regenerating forest, Heath	4.33	0.025<P<0.05
Unidentified fungus	Heath < W.S.F., Regenerating forest	5.44	0.01<P<0.025
Roots	W.S.F. < Regenerating forest, Heath	5.22	0.025<P<0.05

frequency of scats was recorded from the heath site containing *Isopoda*, while a lower frequency possessed unidentified fungus. Three remaining prey categories approached a significant difference. Other Hymenoptera (X^2=3.30, d.f.=1, 0.25<P<0.1), adult Dipterans (X^2=3.57, d.f.=1, 0.25<P<0.1) and Chilipoda (X^2=2.92, d.f.=1, 0.25<P<0.1) were all recorded in higher incidence of scats from the heath site. However discrepancies were not significantly different.

7.1.8 Results - Diet Quantity

In conjunction with recording the presence-absence of the various dietary taxa occurring in faecal samples, food items were divided into 13 broad categories, and the percentage relative to one another was calculated for each faecal pellet by estimating the proportion of the petri-dish occupied by each category. The 13 broad categories were: Blackberry, Invertebrata, Larval Insect, Monocot, Dicot, Seeds, Nodules?, Zygomycete fungus, Gasteromycete fungus, unidentified fungus, Moss, Clover and Roots. A Spearman rank test was employed for each season's data to determine whether one species of bandicoot was consuming a larger volume of a particular food type.

Rank order correlations for autumn (r_s=+0.876, n=12, P<0.001), winter (r_s=+0.776, n=12, 0.005<P<0.01) and spring (r_s=+0.96, n=13, P<0.001) are all positively correlated and not significantly different. Hence, no seasonal differences appeared with respect to the proportions of 13 broad categories in the faeces of the two species.

7.1.9 Discussion

The problems inherent in ascertaining the diet of an animal by faecal analysis have been discussed in Chapter 4. Namely, the differential digestibility of prey items may render soft-bodied prey almost unrecognisable (Watts and Braithwaite 1978; Hall 1980b; Statham 1982; Fox and Archer 1984). Furthermore, results are at best an appraisal of what the population was ingesting coinciding with the sampling sessions (Watts and Braithwaite 1978). The problem of determining accurately the

amount or volume of food items consumed was minimised by selecting a presence-absence method of quantifying faecal material. This method also reduces the bias of individual variation in food preference to give a wider overview of bandicoot diet.

An additional concern relates to the small number of dietary samples collected for *Perameles gunnii* relative to *Isoodon obesulus*. This is partially a reflection of trapping a habitat in which *P. gunnii* appeared to be totally absent. Hence nearly all analyses were conducted on the total diet of *P. gunnii*. However, Kolmogorov-Smirnov two-sample test conducted on faecal pellets collected from both species from the same site at the same time showed no significant difference with respect to the distribution of prey items.

7.1.9.1 Total Diet

In view of the level of taxonomic identification of prey items, and allowing for incorrect taxonomic identity of masticated food substances, the two bandicoot species at Huonville consume similar diets. The only obvious differences to arise were the common occurrence of non-Formicid Hymenopteran containing faeces of *Isoodon obesulus* and their absence in *Perameles gunnii*, and the higher incidence of *P. gunnii* faecal pellets containing Clover.

Greene and Jaksic (1983) have shown that an ordinal level of prey identification seriously underestimates a predator's niche breadth while overestimating niche overlap. The problem of attaining the degree of overlap between the two species in the present investigation was reduced by selecting a higher than ordinal level of prey identification. Further differences may have appeared at lower taxonomic levels; however, the author considers that identifying fragmentary remains below Family level is almost impossible for a majority of Arthropodid prey. Pernetta (1976) observed the shrews, *Sorex araneus* and *Sorex minitus* selecting different families of spiders and opilionids. This would not have been detected at an ordinal level of prey identification.

Isoodon obesulus appeared to be utilising a wider range of prey than *P. gunnii*. However, this was partially a result of the wider range of prey available on the heath site (*P. gunnii* appeared to be absent) and possibly an effect of the small sample size for *P. gunnii* as prey richness may increase with increasing sample size as was shown for *Sminthopsis murina* by Fox and Archer (1984). This could be ascertained by further sampling.

Ants (Formicidae) occurred in higher frequency in *I. obesulus* scats than any other prey taxa, while larvae and armyworm caterpillars (Noctuidae) occurred in a higher percentage of *P. gunnii* faecal samples. The most commonly occurring Coleopteran item in both *I. obesulus* and *P. gunnii* faeces was the Scarabaeidae larvae (curl grubs). I was unable to determine whether this was the Melolonthine larva commonly located in the diet of *I. obesulus* in eastern Victoria (Opie 1980). A prevalent plant component was detected in the scats of both species. Heinsohn (1966) recorded the presence of only blackberries and boxthorn berries. Only the former of these two were detected in faecal pellets in the present study; however various fungi, seeds, monocot, root nodules and mosses amongst other vegetative components were reported in considerable frequency of scats from both species. Moloney (1982) detected seeds and grass in faecal pellets of *I. obesulus* and *P. gunnii* and also considered ants to be the most important dietary item prevailing at the time of his study.

Opie (1980), Stoddart (personal communication, 1985) detected the Mycorrhizal fungi formerly grouped as *Endogone* in the faecal pellets of *I. obesulus* in eastern Victoria. This group of fungi has also been detected in the diet of *Rattus rattus* (Watts and Braithwaite 1978). However, I am unaware of underground puffball (Gasteromycete) fungi being detected in the diets of bandicoots prior to the present investigation.

In retrospect, I could not conclude from faecal analysis whether the bandicoots were consuming earthworms. Hence soft-bodied prey may have been overlooked in faecal analysis. Consistent with this is the observation that slugs were common in pitfall traps (Chapter 7) but not recorded in scats. Heinsohn (1966) reported slugs from *P. gunnii* stomachs

in north-west Tasmania. Brockie (1959) detected Pulmonata in badger scats via radulae, shreds of skin and muscle, shell pieces and occasionally the copulatory dart of snails. If earthworm gizzards are totally digested I am of the opinion that radulae may be overlooked. Furthermore, bandicoots fed snails in captivity are known to break the shells and consume only inner contents (Dr. R. Rose, personal communication, 1985), hence shell pieces will fail to appear in scats.

7.1.9.2 Seasonal Diet

The seasonal diet of *Isoodon obesulus* and *Perameles gunnii* would seemingly reflect what is available at the time with Coleopteran beetles, and E/S/C larvae showing similar patterns in the diet and soil samples or pitfall traps. Hepialidae were not detected in faeces in winter because the two Corbie grubs emerge only in the autumn and spring. Hence although this is another obvious seasonal difference it was not detected in soil sample or pitfall trap analysis. Blackberries were another seasonal component observed in a large number of faecal samples from both species when ripe. The fact that the Zygomycete fungus was detected in a lower frequency in spring samples for both bandicoot species would suggest that availability of this fungus does perhaps decrease in spring. Although, Opie (1980) in eastern Victoria found the subterranean fruiting bodies of the hypogeous sporocarpic fungi were frequently eaten by *I. obesulus* when the soil was moist in winter and spring. The remaining seasonal differences in diet could not be attributed to a seasonal pattern of availability.

Seasonal comparisons between *I. obesulus* and *P. gunnii* were considered statistically invalid because of the small seasonal samples collected for the latter. However seasonal trends for the small number of samples were noted for E/S/C larvae, Blackberries and Zygomycete fungus as for *I. obesulus*.

7.1.9.3 Prey Availability

The basic tenet of pitfall trapping is that ground dwelling animals randomly descend into pitfall traps during the course of normal movements.

Hence, the method assesses activity of animal populations rather than population numbers. However, variation in activity between different animal groups is further compounded by climatic fluctuations, the effects of ground vegetation, and the use of bait or preservative (Greenslade 1964; Greenslade and Greenslade 1971; Statham 1982). The use of attractant e.g. beer (Statham 1982) was not considered as a preservative because this may unnaturally affect invertebrate population activity. However, Statham (1982) found that pitfall traps with beer were catching similar prey to those ingested by *Antechinus stuartii*.

Another problem concerns the duration and diel periods of pitfall trapping (and also soil sampling). Strictly, for a nocturnal predator species, pitfall trapping should be conducted when the predator is active i.e. during nightly hours in conjunction with the predator trapping session. Consistent with this is the finding that cockroaches were not visually detected during the spring bandicoot trapping session, nor were they detected in faecal analysis. However, when retrieving pitfall traps, cockroaches were visually detected, and discovered in cups. As a larger number of cups was not practical within the limits of the present investigation, the duration of prey sampling session was extended. Prey detected in soil samples during daylight hours may bury deeper in the soil at night and be unavailable to the nocturnal bandicoots. Similarly, nightly surface dwelling invertebrates which live deep in the ground during daylight hours e.g. some earthworms, are likely to be detected in faeces and not soil samples.

As a means of sampling prey available to these partially insectivorous Peramelids, pitfall trapping would appear most appropriate, since increased prey activity surely means increased prey availability (Statham 1982; Fox and Archer 1984).

With the above factors in mind and the fact that some items in prey availability analysis may not be detected in faeces, a large number of discrepancies between the frequency of scats and soil samples/ pitfall traps arose.

The suitability of a prey sampling technique to the various prey taxa must be questioned. For instance Corbie grubs (Hepialidae) were

rarely detected by either sampling method. Godsell (1983) assessed the availability of grubs to *Dasyurus viverrinus* by recording the number of their tunnels encountered in quadrat analysis. The seasonal difference in lifecycle possessed by the grubs was not detected in prey sampling as was observed in faecal analysis or from knowledge of their biology. Furthermore, mature Dipteran flies which are unlikely to be detected in soil samples were underrepresented in the diet relative to pitfall traps possibly because their fluid sucking behaviour unduly attracted them to the cups.

Fox and Archer (1984) also reported that ants (Formicidae) were frequent in the diets of *Sminthopsis murina* and *A. stuartii*, but occurred much less frequently in pitfall traps, and hence thought the disparity possibly related to an artefact of pitfall trapping. Siphonaptera (Fleas) and Calliphorid larvae (maggots) are likely to be encountered less frequently in prey sampling analysis because the former inhabits the predator's pelage and the latter were possibly taken from animal carcases or livestock dung.

Pitfall trapping appeared to be highly suitable to the Crustacean group, Isopoda and Amphipoda, however neither occurred in the diet of *P. gunnii* and only slaters occurred in *I. obesulus* in frequencies far less than was measured via pitfall traps. This is consistent with the findings of Godsell (1985) who found both Crustaceans (particularly Amphipods) readily in pitfall traps and soil samples but not in the diet of the Eastern Quoll (*D. viverrinus*). Bandicoot feeding preferences may also be playing an important role in the disparities.

Further evidence suggests that the depth of soil extraction may have been adequate in examining prey availability for *P. gunnii* yet insufficient for *I. obesulus*. Buchmann (unpublished) recorded the depth of 30 diggings of *I. obesulus* to be 21.10 ± 1.45 cm, while *P. gunnii* to be 4.84 ± 0.56 cm. However Lee and Cockburn (1985) state *I. obesulus* may dig to 8 cm.

In view of the large number of disparities between diet and relative availability of prey neither species could be considered quantitatively opportunistic (consuming prey in proportion to their

frequency/occurrence). However, prey sampling techniques were considered to provide a general idea of the relative availability of prey items and not absolute availability. Hall (1980b), Statham (1982), Fox and Archer (1984) all distinguish between the quantitative and qualitative definition of opportunistic feeding. Hence, although a large number of quantitative differences arise, the bandicoots, in particular *I. obesulus*, appear to occupy the qualitative criterion by fact that they sample from almost the entire range of prey available to them.

7.1.9.4 Habitat Diet (*Isoodon obesulus*)

The Brown Bandicoots on the heath site appeared to be utilising a wider range of invertebrate prey than those on the remaining two study sites. This is indicated by the inclusion in the diet of two dietary items (Chilopoda, Isopoda) not detected in faeces from either of the remaining sites although apparently readily available. The possible explanations for this have been discussed in Chapter 6.1.5. Furthermore, the heathland bandicoots appeared to be responding to a wider range of prey available to them, that were not shown in the analysis because of pooling taxonomic groups e.g. two species of Carabidae larvae, Dipteran larvae.

The two Lepidopteran prey groups, Noctuidae and Hepialidae, appeared to be less available on the wet sclerophyll and regenerating wet sclerophyll study sites respectively, while Isopoda appeared in a higher frequency on the heath site (although still high on the forest sites). Hence, for at least these items faecal pellets reflected the local availability of prey. The seemingly lower utilisation of invertebrate taxa on the two forest sites appeared to be accounted for by the greater use of fungus (Table 7.1.7.1). The remaining items did not reflect habitat availability or their occurrence was not examined.

7.1.9.5 Diet Quantity

The estimation of the proportions of 13 broad categories were correlated and only supported the idea of the similarity in diets between the two Peramelid species.

7.1.9.6 Diet From Other Localities

Faecal analysis of bandicoots from various Tasmanian localities revealed essential similarities in diet to that at Huonville. Examination of three *Perameles gunnii* scats from animals trapped behind the University revealed Coleopteran and Hymenopteran legs, wings and antennae, Scarabaeidae larval skins, grass seeds, Blackberry fruits and seeds, Moss, Monocot, grass roots and the Hymenogaster-like Gasteromycete fungus detected in the diet at Huonville. A further pellet collected by Dr. R. Taylor from Harrimont (central-eastern Tasmania) contained Hymenopteran remains, Staphylinidae leg parts, *Hypochaeris radicata* seeds, unidentified seeds, grass roots, and Zygomycete fungus (*Endogone*).

Examination of stomach contents of two roadkilled *Isoodon obesulus* from Lauderdale (south-eastern Tasmania) displayed a wide range of prey items which were considerably easier to identify than those of faecal pellets. Rove beetle larvae, Centipedes, Dipteran pupae, spiders, grasshoppers, Elaterid larvae, Weevil larvae, Chironomid (Dipteran) larvae, ants, bees, armyworms, Corbie grubs, Scarabaeidae larvae, grass seeds, unidentified stone fruits and Zygomycete fungus (*Endogone*) were detected.

7.2 Prey Size Selection

7.2.1 Introduction

Schoener (1974) has expressed the importance of prey size selection as one dimension through which species may partition food resources. Furthermore, Wilson (1975) concluded that while larger predators utilize food unavailable to smaller predators, the reverse is not always true. He predicted that success-of-capture curve for increasing prey size rises rapidly, levels at a plateau (peak efficiency) then slowly declines.

Greene and Jaksic (1983) do not consider prey size classification for computation of niche dimensions to be as relevant as taxonomic prey identification. Their proposals are based on the grounds that a prey individual devoured at a juvenile stage (small size) will not reach adult size. Similarly, consumption of a large-sized prey (adult) will cease

its reproduction, hence reduce the supply of small prey individuals (juveniles) to other predators. However, a majority of authors accept the view that partitioning of resources may exist through consumption of different prey size classes.

Moloney's (1982) captive experiments revealed that while *Isoodon obesulus* was quite adept at killing large prey (mice, rats and chickens), *Perameles gunnii* appeared to be unable to do so. Hence, it may be expected that *I. obesulus* selects larger size classes of invertebrate prey, therefore reducing competition between the two sympatric Peramelid species.

The body length of Arthropod prey may be ascertained by establishing regression equations relating the size of a body fragment to overall length obtained from a reference collection (Calver and Wooller 1982). The technique was successfully applied by O'Neill (1984) in establishing prey length taken by various Tasmanian bat species. A similar technique was employed to examine the length of prey taken by *P. gunnii* and *I. obesulus* at Huonville.

7.2.2 Materials and Methods

Intact, anatomical structures occurring in faecal pellets were infrequently encountered because of considerable mastication of prey items. Hence, prey length could not be measured directly from faecal fragments. The most alliterating and easily classified structures observed in faeces in preliminary investigations were wings and leg fragments (especially tarsi). As wings were often tattered, tarsi from each faecal sample were placed into a small glass petri dish and if belonging to the Orders Coleoptera, Hymenoptera and Hemiptera, the maximum tarsal width was measured under x7 power to the nearest 0.001mm using a graduated eye piece. The above three orders were selected for the following reasons:

(1) Extensive size ranges of the orders were available from faecal pellets, pitfall traps and soil samples.

(2) Whole animals preserved well in pitfall traps.

(3) Faecal fragments preserved well in scats.

The widths of tarsi were measured for animals of the three orders of known length (posterior tip of abdomen to anterior tip of head) and a regression equation established for the relationship between maximum tarsus width and insect body length. Size classes of insects ingested by the bandicoots were then derived from the regression utilising tarsal measurements from faeces.

When calculating the number of various prey size classes appearing in faeces, the minimum number of prey possible from fragments was recorded. Hence, six or less tarsal fragments of identical taxonomic widths related to one insect consumed (Calver and Wooller 1982).

7.2.3 Results

The regression equations relating tarsal width to body length for the three orders of insect examined are highly significant and positively correlated (Table 7.2.3.1).

TABLE 7.2.3.1 Relationship between maximum tarsus width and body length for the insect orders Coleoptera, Hymenoptera and Hemiptera (T.W. = Tarsus Width)

Order	Regression	D.F.	F	P	R^2
Coleoptera	L=67.45T.W.-0.23	62	416.3	<0.001	0.87
Hymenoptera	L=46.76T.W.-0.47	29	86.6	<0.001	0.75
Hemiptera	L=60.65T.W.-0.28	9	95.4	<0.001	0.91

The mean size (length) of prey (three Orders summed) taken by *Isoodon obesulus* and *Perameles gunnii* as derived from tarsi detected in faecal pellets appears very similar (Table 7.2.3.2). Approximately 0.5 mm separates the mean prey size taken by the two species; however, the number of samples presented for *P. gunnii* is extremely small, and this possibly reflects the small prey size range detected for that species relative to *I. obesulus*.

TABLE 7.2.3.2 Mean size of prey taken by *I. obesulus* and *P. gunnii*

Species	Mean Size of Prey (±1 S.D.)	Number of Samples (n)	Range
I. obesulus	11.48±5.88 mm	99	1.53-39.29 mm
P. gunnii	10.96±5.29 mm	5	6.82-17.12 mm

The hypothesis that bigger animals take bigger prey (O'Neill 1984) was tested by regressing the mean weight of each *I. obesulus* capture against mean prey length for that capture. No significant correlation existed ($r = -0.236$, d.f.=30, $0.1<P<0.20$), hence increasing predator weight appeared to have no effect on length of prey taken.

The length of insects taken by *I. obesulus* as derived from tarsal measurements from faeces was compared to the size classes of prey available in soil samples and pitfall traps for each season employing the same size classes as Hall (1980b). The results are presented graphically for autumn, winter and spring in Figs. 7.2.3.1-3. Kolmogorov-Smirnov two-sample tests illustrate that the frequency distribution of prey size classes sampled in pitfall traps and soil samples is significantly different to that estimated from faecal pellets of *I. obesulus* in autumn ($D=0.684$, $n_1=58$, $n_2=48$, $P<0.001$), winter ($D=0.568$, $n_1=57$, $n_2=29$, $P<0.001$) and spring ($D=0.541$, $n_1=190$, $n_2=22$, $P<0.001$). Fig. 7.2.3.4 demonstrates that seasonal differences are manifested in the total diet ($D=0.563$, $n_1=305$, $n_2=99$, $P<0.001$).

Hence the Brown Bandicoots appear to be selecting larger size classes of prey than were detected in pitfall traps and soil samples.

7.2.4 Discussion

Mean prey size selected by *Isoodon obesulus* and *Perameles gunnii* would initially appear very similar. However, a larger sample size for *P. gunnii* is needed for confirmation of this. Hall (1980b) found the average prey size taken by *Antechinus swainsonii* (mean 9.3 mm) was 23% larger than the average prey size for the smaller *A. stuartii* (mean 7.55 mm). He also stated that *A. swainsonii* had an average maximum body

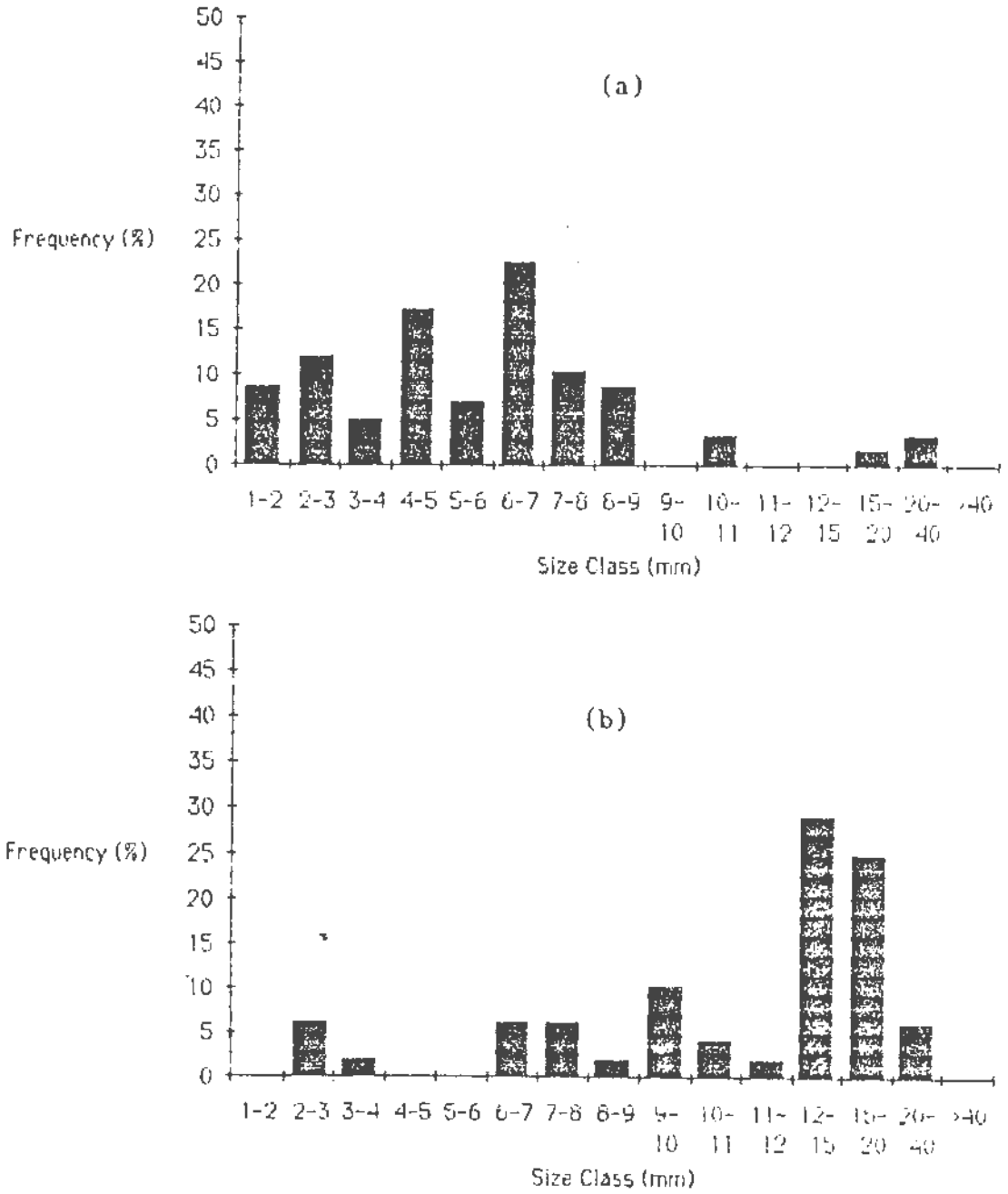

FIG. 7.2.3.1 (a) Frequency distribution of the various size classes of Coleopterans, Hymenopterans and Hemipterans sampled in pitfall traps and soil samples in autumn.

(b) Frequency distribution of the various size classes of Coleopterans, Hymenopterans and Hemipterans derived from faecal samples of *I. obesulus* in autumn.

A prey size of 1-2 mm includes all items larger than 1 mm, up to and including 2.0 mm.
(Size classes as used by Hall 1980b).

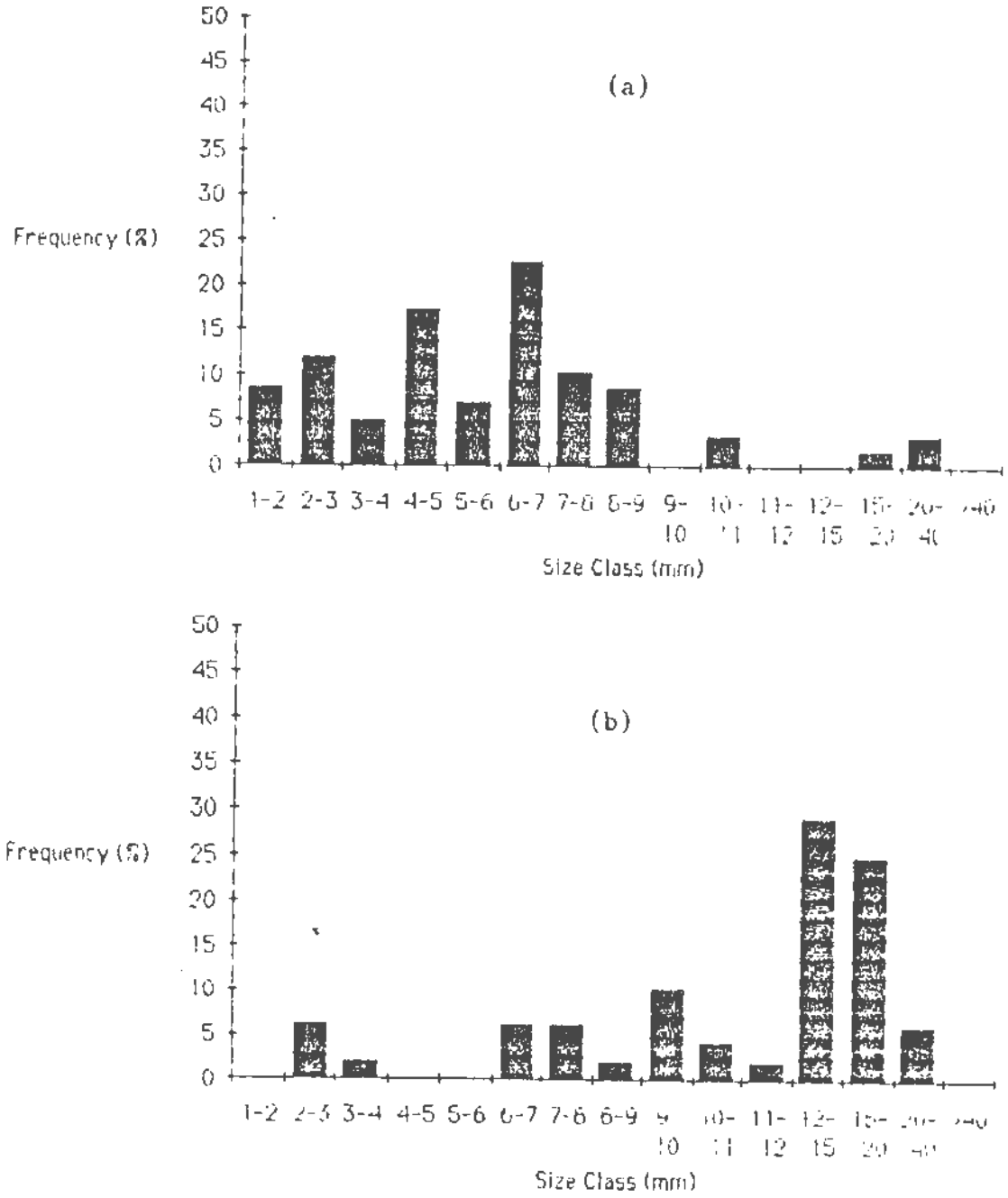

FIG. 7.2.3.1 (a) Frequency distribution of the various size classes of Coleopterans, Hymenopterans and Hemipterans sampled in pitfall traps and soil samples in autumn.

(b) Frequency distribution of the various size classes of Coleopterans, Hymenopterans and Hemipterans derived from faecal samples of *I. obesulus* in autumn.

A prey size of 1-2 mm includes all items larger than 1 mm, up to and including 2.0 mm. (Size classes as used by Hall 1980b).

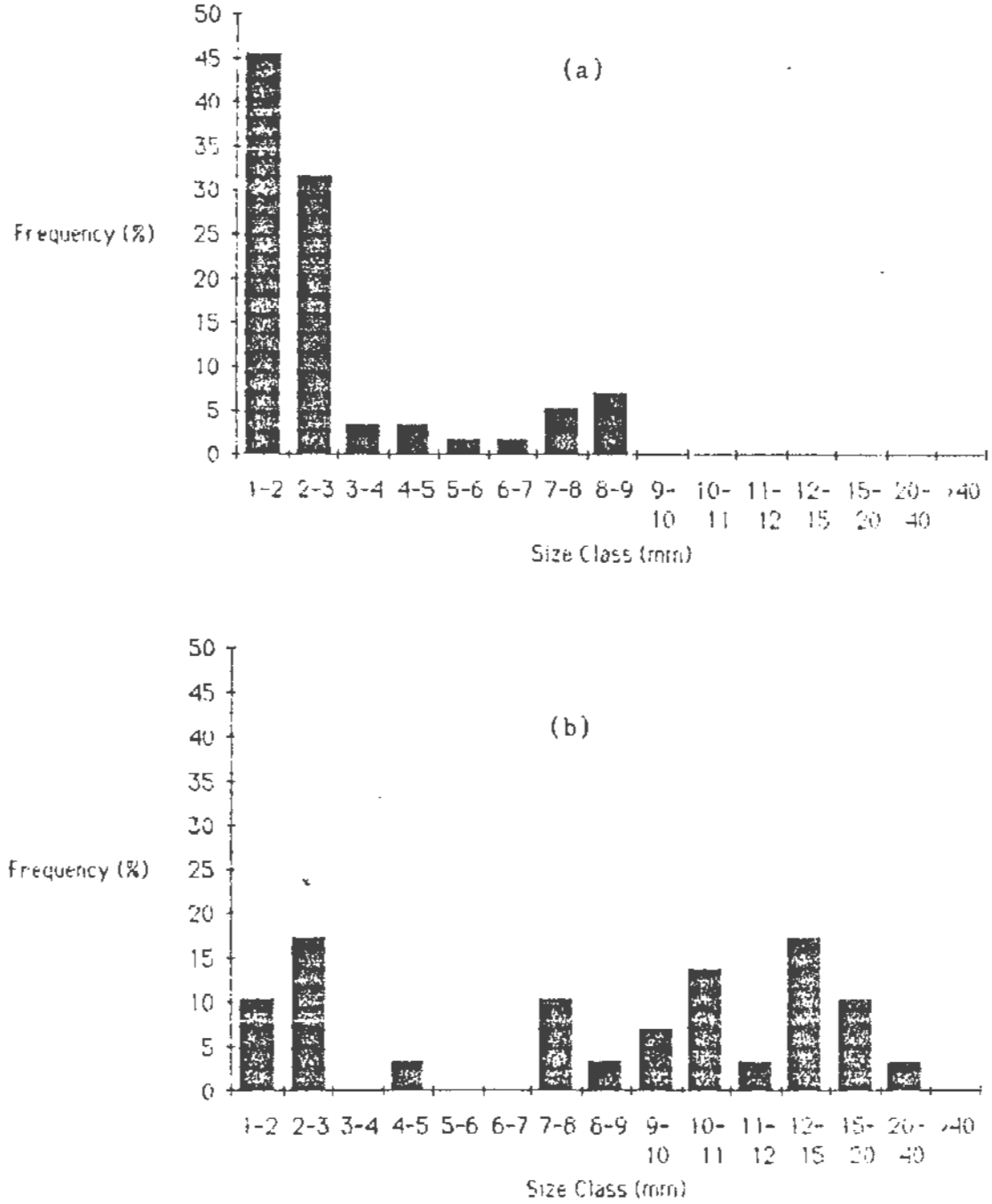

FIG. 7.2.3.2 (a) Frequency distribution of the various size classes of Coleopterans, Hymenopterans, and Hemipterans sampled in pitfall traps and soil samples in winter.

(b) Frequency distribution of the various size classes of Coleopterans, Hymenopterans and Hemipterans derived from faecal samples of *I. obesulus* in winter.

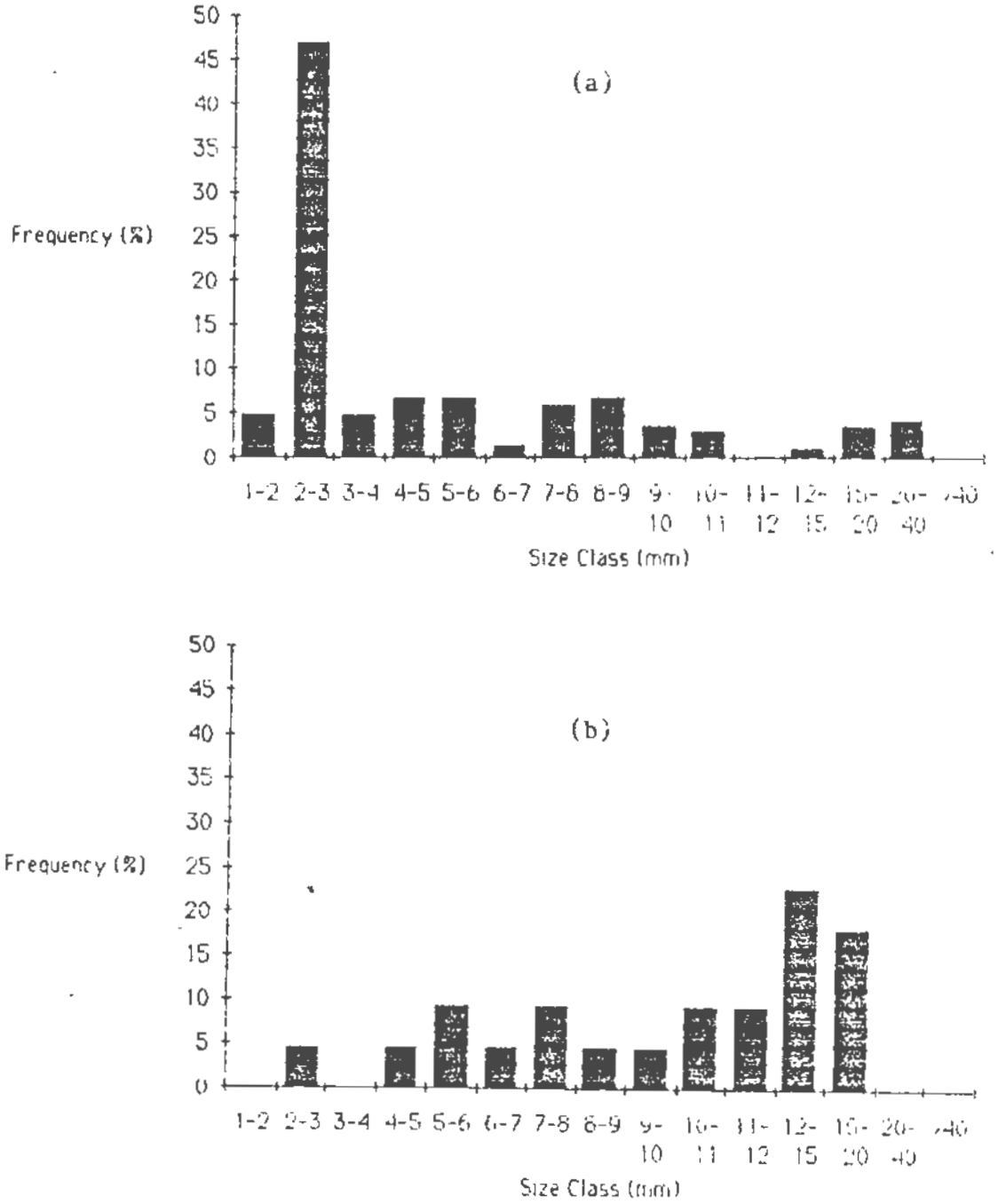

FIG. 7.2.3.3 (a) Frequency distribution of the various size classes of Coleopterans, Hymenopterans and Hemipterans sampled in pitfall traps and soil samples in spring.

(b) Frequency distribution of the various size classes of Coleopterans, Hymenopterans and Hemipterans derived from faecal samples of *I. obesulus* in spring.

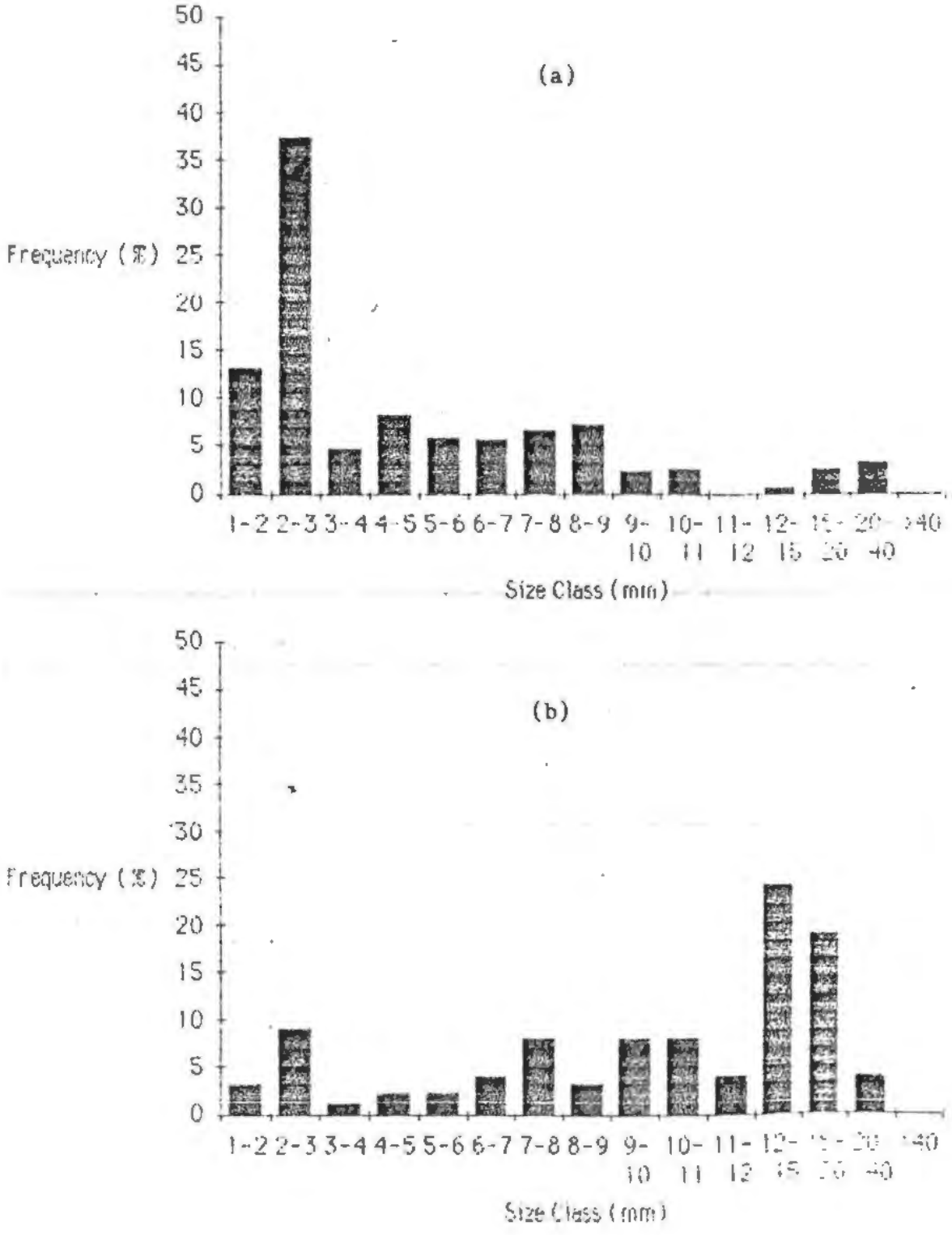

FIG. 7.2.3.4 (a) Frequency distribution of the various size classes of Coleopterans, Hymenopterans and Hemipterans sampled in pitfall traps and soil samples for the three seasons.

(b) Frequency distribution of the various size classes of Coleopterans, Hymenopterans and Hemipterans derived from faecal samples of *I. obesulus* over the three seasons.

weight in May three times that of *A. stuartii*, hence a 23% increase in prey length was roughly equivalent to a 75% increase in predator mass.

The mean prey size for *I. obesulus* and *P. gunnii* would appear only slightly larger than that for the two Dasyurid species. However, Hall's (1980) ratios included elongate prey e.g. centipedes, millipedes, annelids, beetle and moth larvae which are likely to increase the mean prey length taken by a predator. The largest prey items taken by the bandicoots were the Corbie grubs. These were not included in prey size analysis. Since the average weight of male *I. obesulus* in this study was approximately 1350 g (n=14) and for male *P. gunnii* 990 g (n=4), the larger mean prey size for the bandicoots would appear minimal when considering that the mean weights of *A. swainsonii* males in May was 57.4 g and that for *A. stuartii* was 19.2 g (Hall 1980b). The inclusion of elongate prey length measurements would assumingly account for a larger difference in size ingested by bandicoots and *Antechinus* spp. However Ashmole (1968) and Wilson (1975) predicted that larger predators utilize food unavailable to smaller predators, but the reverse was much less true. Hence such a substantial difference may not arise due to selection of smaller prey by larger and smaller predators.

The only remaining estimate of prey size taken by a marsupial I am aware of is Statham's study on *A. stuartii* in New South Wales who considered ground-dwelling arthropods to be taken in the range of approximately 0.5 to 2.0 cm.

The lack of a significant correlation for mean predator (*I. obesulus*) weight and mean prey size is hardly surprising. Opportunistic foraging would assume that predators would devour what was first encountered regardless of its size, as long as the energy reward is sufficient to warrant processing the prey. I suggest that *I. obesulus* consumes what is first encountered, hence such a correlation between the above two variables would not be apparent.

Isoodon obesulus appeared to be selecting larger size classes of prey than what was sampled in pitfall traps and soil samples i.e. when comparing frequency distributions of size class availability and size class taken, the latter shows a significant shift to the right (Figs. 7.2.3.1-4). The difference is particularly noted in autumn and spring,

the winter prey size distribution being slightly flatter. Hall (1980b) observed a similar phenomenon in the two species of *Antechinus* with regards to the size of weevil consumed. Hence *I. obesulus* may be selecting larger Coleopterans, Hymenopterans and Hemipterans while ignoring some of the smaller less profitable prey items, assuming all prey size classes of the three orders are equally trappable in pitfall traps and soil samples.

Fig. 7.2.3.4 shows a tendency for bimodal curves partly due to the inclusion of prey size classes 1-2 and 2-3 mm, and due to the inclusion of elongated Rove beetles of larger size classes in the diet. Hall (1980b) observed bimodality in size class prey curves for *A. stuartii* and *A. swainsonii*. He reported that elongate prey partially caused the departure from Wilson's (1975) predictions of a mono-modal capture-success-curve. The difference is not as pronounced for *I. obesulus* because of the relative infrequency of size classes 3-4 to 6-7 mm in the diet and predominantly selection of larger prey size groups.

Future investigation would take into account the sizes of a wide range of prey including elongate prey e.g. Corbie grubs. Furthermore, the calorific content of bandicoot Arthropod prey could be estimated as suggested by Calver and Wooller (1982) by employing Gowing and Recher's (1984) length-weight relationships to establish prey weight. The energy content is then derived from the energy equation published by Calver and Wooller (1982). Hence, prey length can be instrumental in studies of niche theory, and to represent diet in energetic terms, enhances research on optimal foraging and energy budgets (Calver and Wooller 1982).

CHAPTER 8

DIGESTIVE TRACT MORPHOLOGY

CHAPTER 8

DIGESTIVE TRACT MORPHOLOGY

8.1.1 Introduction

Despite earlier workers describing the diet of bilbies to include grass, bulbous roots, fruits and insects (Hume 1982), Wood-Jones (1924) doubted very much if any bandicoot species consumed plant items. He considered that bandicoots scratched at roots in search of insects, hence considered the group to be insectivorous. Evidence to date suggests that, although diet varies between localities (see Chapter 7.1.1), plant matter is generally ingested. Therefore there can be little doubt that bandicoots and bilbies are truly omnivorous (Hume 1982).

One important nutritional consequence of omnivory is that plant matter remaining undigested provides an additional substrate for bacteria in the hindgut, primarily the caecum. Therefore, omnivorous digestive tracts have increased caecal capacity over carnivores. In addition, an increase in small intestine length and in colon length, diameter or both is apparent (Hume 1982).

The following section examines and compares the stomach morphology of *Perameles gunnii* and *Isoodon obesulus*. Furthermore, comparisons will be made with digestive tracts presented previously in the literature.

8.1.2 Materials and Methods

A deceased, male specimen of *Perameles gunnii* was collected from the golf course study site, and a female *Isoodon obesulus* was obtained as a roadkill from Lauderdale (south-east Tasmania).

Specimens were dissected, the digestive tract removed and photographed for presentation.

8.1.3 Results

The digestive tracts are presented photographically and diagrammatically for *Perameles gunnii* and *Isoodon obesulus* in Figs. 8.1.3.1 and 8.1.3.2 respectively.

In both species, the stomach and small intestine are simple. The most conspicuous feature is the hindgut caecum of moderate size prior to the colon. Unidentified anal glands, possibly paracloacal glands, arise at the base of the colon in the digestive tract of *P. gunnii*. Anal glands in *I. obesulus* were possibly destroyed during dissection or when the animal was struck by the vehicle, although possible remnants are apparent in the presentation. It is not known whether female *I. obesulus* possess anal glands.

8.1.3.4 Discussion

Hume (1982) considered that the bandicoots digestive tract anatomy and function reflected their omnivorous dietary habits. The results presented here are consistent with the observations concerning digestive tracts presented for the Long-nosed Bandicoot, *Perameles nasuta* and the Rabbit-eared Bandicoot, *Macrotis lagotis* by Hume (1982). The oesophagus follows with a simple stomach and small intestine, an enlarged hindgut caecum for microbial fermentation of plant products, and a colon of moderate length. Hume (1982) further presents a digestive tract of a *Perameles* sp. This specimen possessed a smaller caecum but a colon of greater diameter. Minimal difference if any existed between the digestive tracts of the two species involved in the present investigation.

Further evidence for the bandicoots omnivorous diet from Kerry (1969) indicates that the levels of activity of trehalase and cellubiase were substantial in *P. nasuta* and *I. obesulus*. Trehalose is a disaccharide found solely in insects while cellubiose is formed during katabolism of cellulose. In contrast the insectivorous/carnivorous Dasyurids *Antechinus stuartii* and *Dasyurus maculatus* displayed high levels of trehalase, but not cellubiase. Hence, while Peramelids

appear to possess enzymes capable of utilizing sugars of insect and plant matter, Dasyurids apparently only possess high levels of enzymes capable of breaking down the former. Furthermore, Waring *et al.* (1966) have demonstrated that the passage rate of digesta through the bandicoot gut is slower than that for carnivores e.g. *A. swainsonii* (Cowan *et al.* 1974) probably reflecting the longer time required to break down plant products.

FIG. 8.1.3.1 Photographic and diagrammatic representation of the digestive tract of *Perameles gunnii*

FIG. 8.1.3.2 Photographic and diagrammatic representation of the digestive tract of *Isoodon obesulus*

CHAPTER 9

HABITAT UTILIZATION

CHAPTER 9

HABITAT UTILIZATION

9.1.1 Introduction

The macro-habitat preferences of *Isoodon obesulus* and *Perameles gunnii* have been well documented by Heinsohn (1966), with *P. gunnii* showing extensive use of open areas and *I. obesulus* being more constrained by densely vegetated habitat characteristics. Moloney (1982) failed to find such a distinct macro-habitat preference, concluding that selection of microhabitats may be more important in reducing competition between the two species. Furthermore, Gordon (1971, 1974a) has defined the habitat preference of the Northern Brown Bandicoot (*Isoodon macrourus*) to be moderately dense ground cover near ground level e.g. grass or herbage, sufficiently open to permit free movement. It has seldom been reported from grazed areas (Gordon 1971).

Cheal (1979) emphasizes the importance of vegetation analysis in small mammal research, and recently Cockburn (1978), Stoddart and Braithwaite (1979), Gullan and Robinson (1980) have shown that floristic variation correspond to environmental factors, and determine the accordance of the abiotic environment for different species of small mammals. Floristic classification could also reflect food resource availability for various small mammals occupying various niches. In addition, Braithwaite and Gullan (1978), Braithwaite *et al.* (1978), Hall and Lee (1982) and Norton (1982) have recognised the importance of structural vegetation parameters in defining small mammal habitats. Hence, microhabitat variation may reflect the relative abundance of small mammal species.

To date, only the study of Braithwaite and Gullan (1978) has examined structural and floristic parameters of vegetation defining microhabitat preference of a bandicoot species (*I. obesulus*), although Stoddart and Braithwaite (1979) and Opie (1980) provide a comprehensive investigation into the response of *I. obesulus* to the floristic groups derived from Braithwaite and Gullan's (1978) study. Enquiries revealed that *I. obesulus* exhibits a clear preference for newly

regenerating heathland.

The following investigation attempts to examine the macro- and microhabitat preferences of *I. obesulus* and *P. gunnii*, and in doing so, to measure structural and floristic parameters important in specifying the latter.

9.1.2 Materials and Methods

Trapping techniques, size of grids, number of traps per study site and examination of captured subjects have been described in Chapters 2.1 and 6.1.2.

9.1.2.1 Macrohabitat Analysis

Macrohabitat utilization was assessed by calculating the number of captures of bandicoots at trap stations located in seven vegetation formations. Trapping rate was expressed as the number of captures per hundred trap nights (stations) situated in each of the stands.

Spotlighting data were obtained by randomly traversing the study sites on foot and recording the number of bandicoot sightings. The vegetative characters of the places where sightings were made were recorded.

9.1.2.2 Microhabitat Analysis - Vegetation Description

Floristic Description: A 3 x 3m quadrat was laid out at each trap station and every plant species growing in the quadrat or projecting within its boundary was recorded. A visual estimate of the cover/abundance of each species in the quadrat was additionally noted, according to the Braun-Blanquet scale (see Mueller-Dombois and Ellenberg 1974).

Structural Description: Seven point quadrats were taken within each trap station quadrat using a 1 m high and 1 m wide point frequency frame (see Mueller-Dumbois and Ellenberg 1974). The wooden frame had a series of 10 guide holes drilled 10 cm apart, in two parallel, horizontal bars. The frame was divided vertically into three equal height intervals, each 33.3 cm apart.

The frame was held perpendicular to the vegetation to be measured. A steel rod (6 mm diameter) was lowered vertically into the centre guide hole and vegetation touched by the rod was recorded at each of the three height intervals for the seven points taken. Visual estimates of contact were employed above 1 m and this value for each station was reinforced by assigning a percentage cover value for vegetation above 1 m, and converting this value to a score out of seven. A point quadrat was taken by holding the frame diagonally in each corner, and three were extracted across the centre of each trap quadrat.

The structural description ofeach station was therefore quantified, allowing a variation at each of four height intervals from zero to seven.

Classification and Ordination

Structural and floristic quadrat data were classified employing the Clustan Analysis Package (Wishart 1978) available on the Tasmanian University Centre's Burroughs B6800.

Concisely, the classification method utilizes a hierarchial agglomerative clustering strategy to group structural and floristic data, and operates on metric distance using the within-group sum of squares (known as Ward's Method) as the agglomerative criterion (Orloci 1967). Successive cycles of agglomeration are undertaken in a way which minimises the within-group sum of squares, and accordingly maximises differences between groups at each clustering cycle.

The process eventuates in the construction of a hierarchy of dichotomous branching until a subjectively designated level of association is reached; in the present investigation, when separation of clustering cycles appeared to be spurious. Appendix D presents the dendrograms horizontally with case identifiers (trap stations) printed down the left side of the page, and fusions across the page plotted according to the value of the clustering criterion (i.e. to scale). Vertical bars directly adjacent to the case identifiers depicts the floristic and structural groups recognised.

9.1.3 Results

9.1.3.1 Results - Macrohabitat Analysis

Fig. 9.1.3.1a presents the utilization of different vegetation types by *Isoodon obesulus* and *Perameles gunnii* on the three sites pooled, determined by live-trapping results. The results indicate that *I. obesulus* was caught in all vegetation types except in dense wet sclerophyll forest, being captured only on the forest and pasture edge. The highest number of captures was recorded over a small number of trap nights (23) on the golf course fairways. Regenerating heath appeared to be extremely important whereas open pasture and scrub adjoining open pasture appeared to be relatively unimportant.

Results for *P. gunnii* are inconclusive because of the low number of captures recorded. Individuals appeared to be captured predominantly in regenerating wet sclerophyll forest, sufficiently open to permit free movement. One capture occurred on the wet sclerophyll forest and pasture edge.

Specific habitats of spotlighting observations were assumed to represent preferred foraging habitats because previous investigations (Heinsohn 1966; Moloney 1982) have shown *I. obesulus* and *P. gunnii* to be foraging for a major proportion of their time active. Observations were pooled for seasons and recorded as the number of sightings per spotlighting hour (Table 9.1.3.1a).

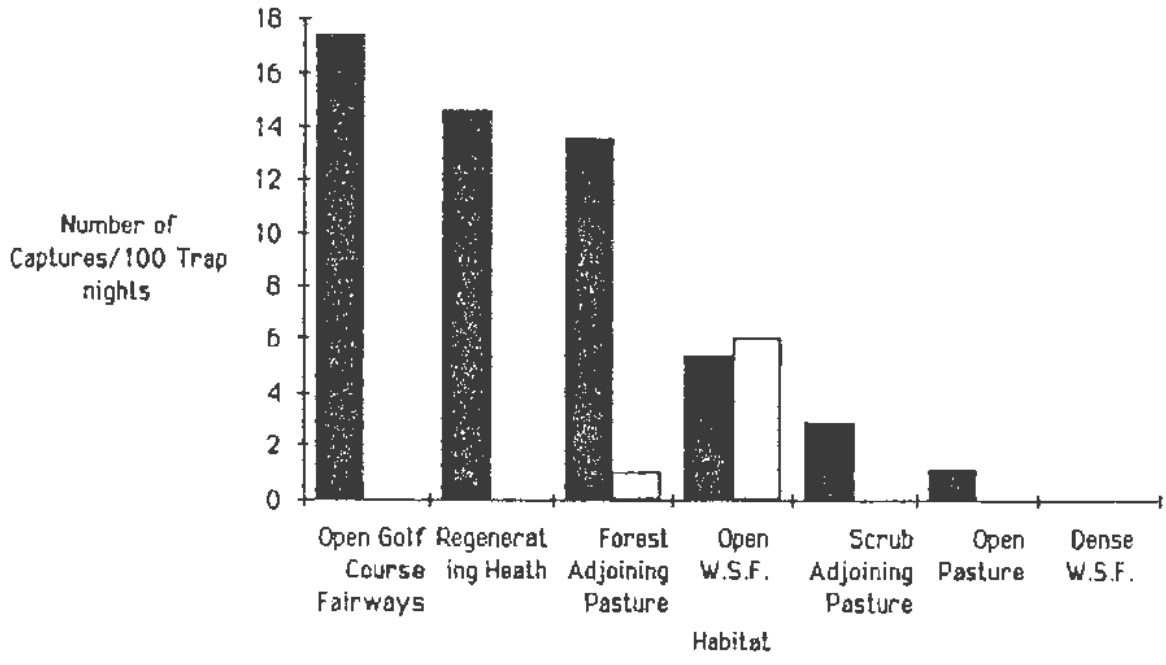

FIG. 9.1.3.1a Utilization of different vegetation types at Huonville by *I. obesulus* (solid bars) and *P. gunnii* (open bars) as determined by trapping results. Open W.S.F. denotes wet sclerophyll forest sufficiently open to permit free movement.

TABLE 9.1.3.1a Number of sightings per spotlight hour and ratios of *P. gunnii* to *I. obesulus* on each of the three study sites surveyed (pooled for all seasons)

	Wet sclerophyll forest-open pasture	Regenerating wet sclerophyll forest -golf course fairways	Regenerating wet heath-pasture
P. gunnii sightings	2.11	11.2	-
I. obesulus sightings	0.16	0.4	-
Ratio *Perameles* to each *Isoodon*	13.2	28.0	-
Number of spot-lighting minutes	370	300	110

Isoodon obesulus appeared less likely to be observed active at night than *P. gunnii.* When sighted, Brown Bandicoots generally were adjacent to, or a short distance from dense vegetation e.g. Blackberry clumps when observed in the pasture or when observed on the golf course, only a short distance from dense vegetation of the study site. Barred Bandicoots were most often sighted in open areas e.g. golf course fairways, pasture at considerable distances from cover although some observations were reported from the forest edge of the golf course site. No observations were made of either species on the wet heath-pasture site possibly due to the low dense ground cover, although no *P. gunnii* were observed on the adjacent open pasture in comparison to other sites.

9.1.3.2 Results - Microhabitat Analysis Wet Sclerophyll Forest - Open Pasture Site

Floristic Groups: Floristic quadrat data were assembled into three groups (see Appendix D) and two unassigned quadrats. In broad terms, floristic group A represented where forest adjoined open pasture, B reflected the inner forest portions and C the open pasture. A majority of quadrats contained a moderate to dense layer of Blackberries (*Rubus fruticosus*). However, the clustering programme appeared to show that an array of shrubs and herbs whose sporadic occurrence within a floristic group was shared between groups, but whose overall contribution to any one group was negligible.

Group FA: The dominant canopy comprised *Eucalyptus ovata.* A secondary layer was usually absent; however the sedge *Lepidosperma elatius* was conspicuous in the sedge layer with *R. fruticosus.* A sparse to moderate cover of the grasses *Poa annua* and *Dactylis glomerata,* and white clover (*Trifolium repens*) constituted the field layer.

Group FB: The dominant canopy in this group consisted of Swamp Gum (*E. ovata*) with a secondary understorey of Currajong (*Asterotrichion discolor*), Dogwood (*Pomaderris apetala*) and occasionally Silver Wattle (*Acacia dealbata*). A shrub layer comprised a sparse to moderately dense layer of Blackberries (*R. fruticosus*). A ground layer, when present, usually consisted of a rare layer of grasses (*P. annua,*

D. glomerata and an *Agrostis* sp.).

Group FC: This group usually lacked a tree canopy and was represented by a dense field layer of the grasses *P. annua* and *D. glomerata*, and a sparse layer of the *Agrostis* sp. Usually blackberries within the pasture projected into the quadrat forming a moderately dense layer, with a rare occurrence of *Juncus australis*.

Unassigned Quadrats: These did not share sufficient numbers of species with any assigned floristic group or with each other to be placed into a group. A low diversity and a low abundance of species appeared to reside in this group.

Structural Groups: Three structural groups were derived by the clustering programme.

Group SA: Cover above 1 m and between 33.3 - 100 cm was sparse in this group. The ground cover (0 - 33.3 cm) was relatively thick.

Group SB: This group reflected a majority of the inner forest quadrats, hence the ground layer was rare. The layer between 33.3 - 66.6 cm was slightly thicker but very thin between 66.6 - 100 cm. However a relatively thick canopy (above 1 m) was apparent.

Group SC: A dense ground layer up to 33.3 cm with moderately dense cover thereafter characterised this group.

The distribution of floristic and structural groups as derived from the clustering analysis, structural group averages at each tier and the mean number of captures per trap site for floristic and structural groups are presented in Fig. 9.1.3.2a and Tables 9.1.3.2a-c.

TABLE 9.1.3.2.a Structural group averages at each vegetation tier for study site 1. (The maximum possible value is 7 i.e. 7 of 7 pins dropped making contact with vegetation).

Vegetation Tier	Structural Group		
	SA	SB	SC
0–33.3 cm	5.1	1.0	6.0
33.3–66.6 cm	1.6	2.2	3.1
66.6–100 cm	0.2	0.3	2.3
>100 cm	2.6	4.5	2.9

TABLE 9.1.3.2.b Analysis of bandicoot captures by floristic groupings on the wet sclerophyll forest-open pasture study site. (UA denotes unassigned quadrat A, UB denotes unassigned quadrat B). Values are expressed as the mean number of captures per number of trap sites.

Floristic Group	Mean number of captures per trap site		Number of sites
	I. obesulus	*P. gunnii*	
FA	1.1	0	10
FB	0	0	7
FC	0.2	0	11
UA	2.0	0.5	1
UB	1.0	0	1

TABLE 9.1.3.2.c Analysis of bandicoot captures by structural groupings on the wet sclerophyll forest-open pasture study site.

Structural Group	Mean number of captures per trap site		Number of sites
	I. obesulus	*P. gunnii*	
SA	0.7	0.07	16
SB	0.3	0	8
SC	0.3	0	6

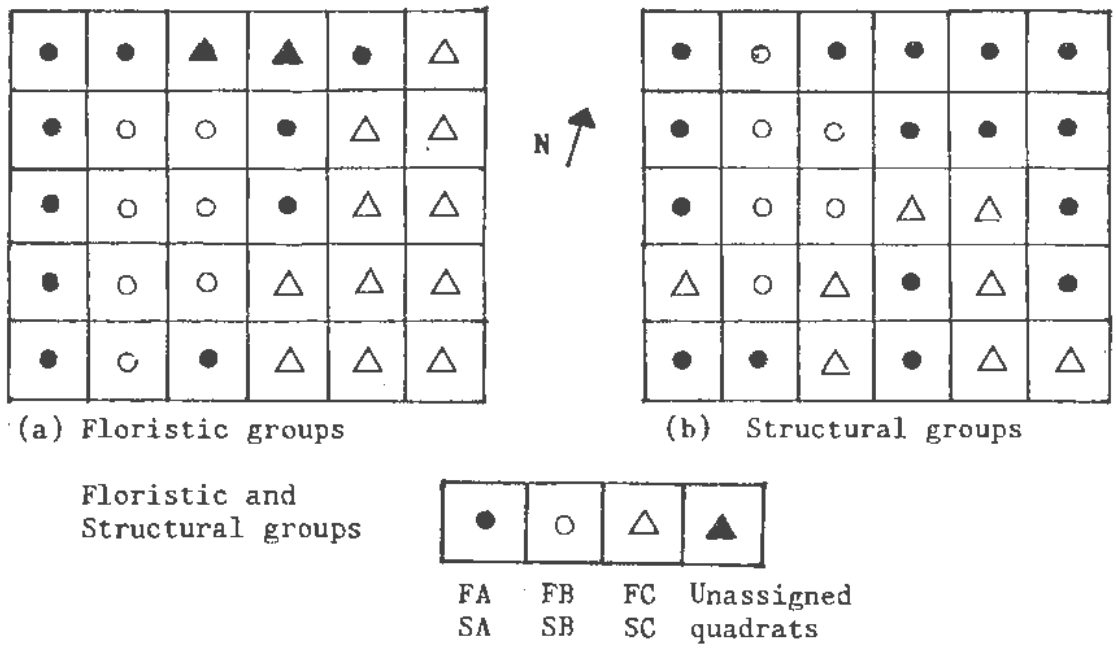

FIG. 9.1.3.2a Distribution of floristic and structural groups over the wet sclerophyll forest-open pasture study site as derived from the clustering programme.

Data collected for *Perameles gunnii* are scarce and inconclusive. For *Isoodon obesulus*, the mean number of captures per trap site is significantly different between floristic groups (X^2=15.85, d.f.=4, 0.001<P<0.005), but not for structural groups (X^2=2.46, d.f.=2, 0.25<P<0.50). Hence the capture rate appeared to be significantly higher for floristic group FA, unassigned quadrats UA and UB, while lower for floristic quadrats FB and FC.

Regenerating Wet Sclerophyll Forest - Golf Course Fairways

Floristic Groups: Three floristic groups were defined by the sorting programme (Fig. 9.1.3.2.b). The sedge, *L. elatius*, contributed considerably to all quadrats, excepting group FC.

Group FA: Regenerating Swamp Gum (*E. ovata*) provided the dominant canopy for this group while *Hibbertia empetrifolia* consistently comprised the dominant shrub layer. *Schoenus apogon* dominated the field layer with *Poa poiformis*. An introduced grass, *Bromus* sp. also prevailed in the field layer.

Group FB: This group also retained *E. ovata* as the dominant canopy with a secondary understorey of *Leptospermum scoparium* and a sparse covering of *Olearia floribunda*. A *Stipa* sp. of grass replaced *Poa poiformis* when the latter was absent from the quadrat.

Group FC: The low floristic diversity of the golf course fairways was reflected in this group. A tree and shrub layer was absent; the field layer comprised predominantly the Compositae, *Hypochaeris radicata*, the Moss, *Lembophyllum divulsum*, the grasses *Agrostis capillaris*, *Bromus* sp. and an unidentified grass species.

Structural Groups: Structural group averages for each vegetation tier are presented for this site in Table 9.1.3.2.d. Structural quadrats were assembled into four groups (Fig. 9.1.3.2.b).

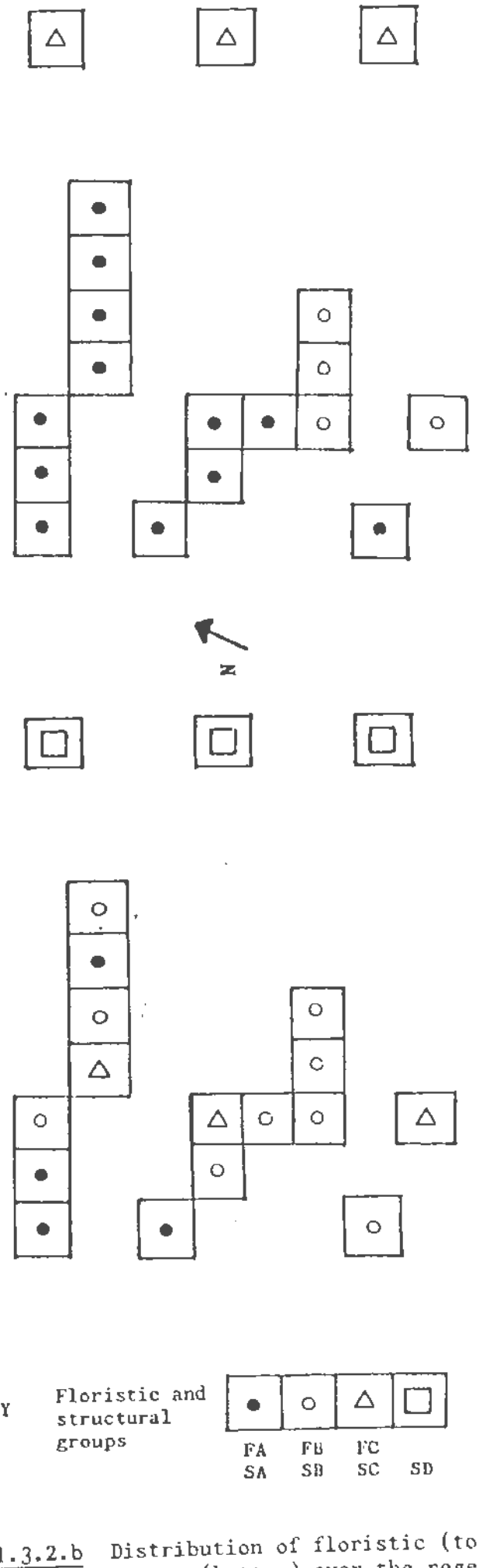

FIG. 9.1.3.2.b Distribution of floristic (top) and structural groups (bottom) over the regenerating wet sclerophyll forest-golf course fairways study site as derived from the clustering programme.

Group SA: Cover to 33.3 cm was dense in this group with a sparse layer to 100 cm and a relatively thick canopy above 1 m.

Group SB: A sparse cover above 66.6 cm and a moderately dense cover between 33.3-66.6 cm was apparent in this group. A thick cover below 33.3 cm was additionally observed.

Group SC: A very thick cover was recorded below 33.3 cm in this group and a moderately dense layer to 66.6 cm. The tier between 66.6-100 cm and above 1 m was very sparse.

Group SD: A single group was assembled for the 3 quadrats on the golf course fairways with only a dense layer below 33.3 cm being recorded. Although not detected in this type of analysis, the lower tier present was actually below 5 cm and not 33.3 cm.

TABLE 9.1.3.2.d Structural group averages at each vegetation tier for study site 2.

Vegetation Tier	Structural Group SA	SB	SC	SD
0-33.3 cm	5.3	6.6	7.0	6.0
33.3-66.6 cm	2.3	3.6	3.3	-
66.6-100 cm	1.0	1.8	-	-
>100 cm	5.0	1.8	1.3	-

TABLE 9.1.3.2.e Analysis of bandicoot captures by floristic groupings on the regenerating wet sclerophyll forest-golf course fairways site.

Floristic Group	Mean number of captures per trap site *I. obesulus*	*P. gunnii*	Number of Sites
FA	0.8	0.5	12
FB	0	1.0	4
FC	1.3	0	3

TABLE 9.1.3.2.f Analysis of bandicoot captures by structural groupings on the regenerating wet sclerophyll forest-golf course fairways study site.

Structural Group	Mean number of captures per trap site		Number of sites
	I. obesulus	*P. gunnii*	
SA	0.8	1.0	4
SB	0.6	0.4	9
SC	0.3	0.6	3
SD	1.3	0	3

The mean number of captures per trap site on the golf course study site is not significantly different between floristic groups for *I. obesulus* (X^2=4.76, d.f.=2, 0.05<P<0.1) or *P. gunnii* (X^2=3.23, d.f.=2, 0.05<P<0.1). Similarly, the mean number of captures per trap site for structural groupings is not significantly different for *I. obesulus* (X^2=3.06, d.f.=3, 0.25<P<0.50) or *P. gunnii* (X^2=3.51, d.f.=3, 0.25<P<0.50).

Wet Heath - Pasture

Floristic Groups: Floristic quadrats were assigned to three groups and one unassigned quadrat on the wet heath-pasture site (Fig. 9.1.3.2.c). All quadrats contained a sparse covering of the Compositae *H. radicata*.

Group FA: The dominant canopy of this group comprised low, regenerating *E. ovata* seedlings. *Restio complanatus* contributed considerably to the sedge layer while *A. capillaris* and a *Bromus* sp. were the dominant grasses.

Group FB: When a canopy was present in this group *E. ovata* was the contributor to the quadrat with a sparse to moderately dense layer of *Cassinia aculeata*. *Rubus fruticosus* dominated the shrub layer while *L. elatius* and *Lomandra longifolia* were present in the sedge layer. *Agrostis capillaris* and an unidentified grass species provided a moderate to moderately dense ground layer.

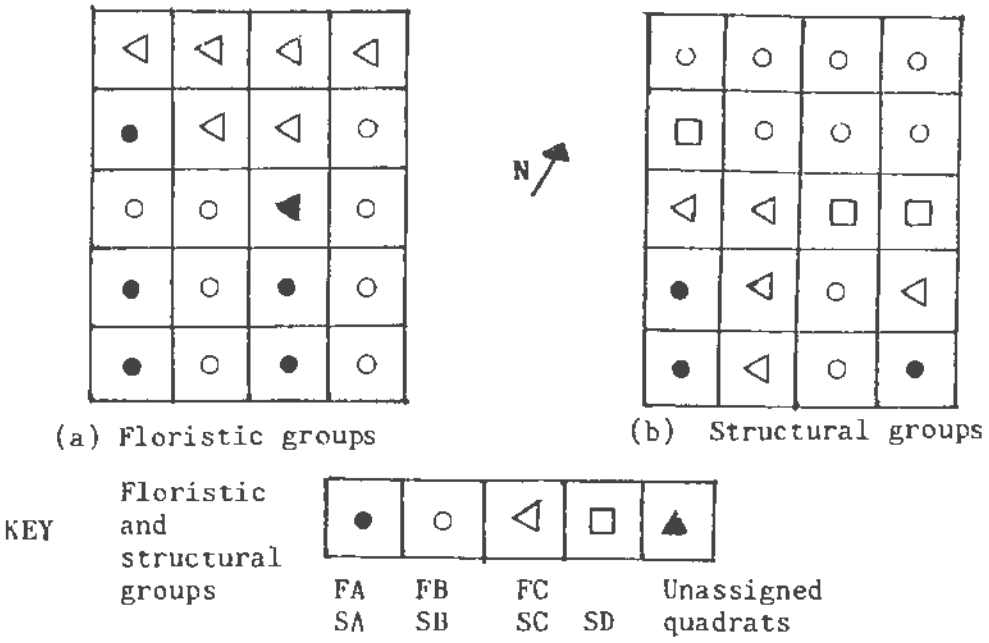

FIG. 9.1.3.2.c Distribution of floristic and structural groups over the wet heath study site as derived from the clustering programme.

Group FC: This group represented four pasture trap sites and two sites where heath adjoined pasture hence was species poor and lacked a canopy. *Cassinia aculeata* and *R. fruticosus* were the dominant shrubs with *J. australis* common in the sedge layer. *Hypochaeris glabra* was the dominant herb while *Cynodon dactylon* and the unidentified grass species were prominent Monocots.

Unassigned Quadrats: One unassigned quadrat was obtained from the analysis, which could not be placed into one of the above groups.

Structural Groups: The mean values for structural groups are presented in Table 9.1.3.2.g. Four groups were recognised. A character of this whole site was the sparse cover above 66.6 cm possibly reflecting the young age of the heath site.

Group SA: This group was characterized by a dense layer below 33.3 cm, but sparse layers above that tier.

Group SB: A thick layer below 33.3 cm also characterized this group. A sparse layer existed between 33.3-66.6 cm with a very thin upper canopy (above 66.6 cm).

TABLE 9.1.3.2.g Structural group averages at each vegetation tier for study site 3.

Vegetation Tier	Structural Group SA	SB	SC	SD
0–33.3 cm	6.0	6.4	4.8	5.7
33.3–66.6 cm	0.7	0.6	0.8	3.3
66.6–100 cm	1.0	-	-	-
>100 cm	0.7	-	1.4	0.3

Group SC: A sparse upper canopy, very thin middle layers and a moderately dense lower layer was apparent in this group.

Group SD: Cover below 33.3 cm was thick in this group and moderately dense between 33.3–66.6 cm. Cover above 66.6 cm was extremely thin.

Tables 9.1.3.2h-i present the mean number of captures per trap site for floristic and structural groupings respectively.

The mean number of *I. obesulus* captures per trap site between groupings is significantly different for floristic groups (X^2=10.89, d.f.=3, 0.01<P<0.025), but not for structural groups (X^2=4.42, d.f.=3, 0.1<P<0.25). Hence there appeared to be greater use of floristic group FA and the unassigned quadrat while lesser use of groups FB and FC by *I. obesulus*.

TABLE 9.1.3.2.h Analysis of bandicoot captures by floristic groupings on the wet heath-pasture site. (UA denotes unassigned quadrat).

Floristic Group	Mean number of captures per trap site *I. obesulus*	Number of sites
FA	2.0	5
FB	0.9	8
FC	0.2	6
UA	2.0	1

TABLE 9.1.3.2.i Analysis of bandicoot captures by structural groupings on the wet heath-pasture site.

Structural Group	Mean number of captures per trap site *I. obesulus*	Number of sites
SA	1.3	3
SB	0.4	9
SC	1.4	5
SD	1.3	3

9.1.4 Discussion

9.1.4.1 Macro-habitat Analysis

The area in which a species is trapped may not necessarily reflect its preferred habitat. Both bandicoot species appear to select nest sites in densely vegetated habitats, however move into different habitats at night to forage (Heinsohn 1966; Moloney 1982). The occurrence of intra- and interspecific competitive interactions and food availability may constrain individuals to different sub-optimal habitats (Moloney 1982). Results relating to habitat analysis must therefore be treated with caution.

The high capture rate of *Isoodon obesulus* on open golf course fairways may represent a bias in the results due to the small number of trap nights recorded there. However, it is interesting that Brown Bandicoots were venturing considerable distances from cover since most investigations (Heinsohn 1966; Moloney 1982) have shown that *I. obesulus* shows a preference for areas containing low, dense ground cover. Heinsohn (1966) and Moloney (1982) did however record low captures of this species in open paddocks or pastures (also recorded in the present study). Buchmann (unpublished) also reported the species from open grassland.

The importance of regenerating heath in *I. obesulus* captures is consistent with the observations of Stoddart and Braithwaite (1979) and Opie (1980). The former further demonstrated this tendency was

most clearly exhibited by juvenile females. Similar phenomena have been reported for *I. obesulus* by Heinsohn (1966) and Moloney (1982), for *Isoodon obesulus* and the Long-nosed Bandicoot, *Perameles nasuta* (Newsome *et al.* 1975) and for the Northern Brown Bandicoot, *Isoodon macrourus* (Fox 1982a). However, these were fire-affected areas and not necessarily regenerating heathlands.

No captures of either species were recorded in dense wet sclerophyll forest but were reported on the edge of this forest where it adjoined open pasture, suggesting that bandicoots may have been trapped while emerging to feed in pasture near to, or farther away from the forest (as indicated by spotlighting data).

The highest capture rate for *P. gunnii* was recorded on the golf course site where the regenerating forest possesses dense ground cover sufficiently open to permit free movement. Heinsohn (1966) suggested that *P. gunnii* showed extensive use of open areas, although did report the animal from a variety of habitats. Buchmann (unpublished) recorded highest capture rates in low grass covered areas, but also trapped *P. gunnii* in open grasslands, shrubberies and various forest formations.

Spotlighting data are not considered to represent relative numbers of animals utilising an area but the relative activity of species utilising habitat types. Counts may be higher than numbers utilising an area because individuals may be counted more than once. Animals utilising dense areas are less likely to be censussed than animals employing open areas. However, with this in mind results only reinforce the observation that *P. gunnii* utilises open areas e.g. pasture, golf course fairways and *I. obesulus* is most active in densely vegetated habitats.

The ratios provided are consistent with those procured by Heinsohn (1966) in a similar situation whereby open areas were bordered by dense habitat. Furthermore, all *I. obesulus* sightings were close to scrubby areas. In comparison, *P. gunnii* showed extensive activity in open areas at considerable distances from cover. However, some observations of *P. gunnii* were observed near to, or on the forest sites and were readily trapped with *I. obesulus* in regenerating wet sclerophyll forest.

The possibility emerges that these animals were trapped prior, or after foraging in open areas.

Although no observations of *I. obesulus* were recorded at considerable distances from cover, four specimens were trapped at stations established on the fairways in winter. No captures for comparison were recorded for spring (Brown Bandicoots appeared to be absent from this site). Fewer observations were recorded for *P. gunnii* in winter although thick fog and equipment failure rendered observations difficult. The possibility arises that during winter, *P. gunnii* is far less active in colder temperatures, allowing *I. obesulus* to forage further into open areas. However, further trapping, in conjunction with telemetry may provide the answer to this view. I suggest that the number of traps set in open habitats appeared to be insufficient to encounter the activity of *P. gunnii* in those areas, although they appeared trap shy relative to *I. obesulus*. Furthermore, telemetry may be used to define territories of these sympatric Peramelids.

9.1.4.2 Micro-Habitat Analysis

Isoodon obesulus, in eastern Victoria, has been associated with dry heathland communities regenerating after clearing and showing decreasing structural complexity (Braithwaite and Gullan 1978) and dominated by the sedges *Gahnia sieberana* and *Schoenus brevifolius* (Stoddart and Braithwaite 1979). No previous attempt has been attempted to determine the microhabitat preferences of *Perameles gunnii*.

Few microhabitat preferences could be attained for either species from the present investigation. As with macro-habitat utilization, a large number of variables may affect the potentially viable microhabitats occupied by individuals e.g. intra- and interspecific competition, social interactions, food requirements, avoidance of predators etc. (see Hall and Lee 1982). However, Braithwaite *et al.* (1978) considered that resource partitioning by heathland communities was primarily reflected by dietary requirements.

Isoodon obesulus appeared to show significantly higher use of floristic group FA and the two unassigned quadrats on the wet sclerophyll forest site as revealed in the mean number of captures. This may have been food orientated since the densest cover of blackberries existed in these quadrats and sedges have been known to provide Zygomycete fungus for *I. obesulus* (Professor D.M. Stoddart, personal communication, 1985); *Lepidosperma elatius* was common in this group. Furthermore *Trifolium repens* was present in this group. *T. repens* leaves and seeds (predominantly) were detected in the diet. Structural parameters appeared to be unimportant in defining the microhabitat of *I. obesulus*. Data for *P. gunnii* is insufficient to warrant comment (see Tables 9.1.3.1.b-c).

Analysis of bandicoot captures by floristic groupings approached a difference for both species on the golf course site but were not significantly different. There may be a bias introduced by the small number of trap sites for groups FB and FC although a slight hint of partitioning is apparent. If microhabitat preference is apparent, the FB group of which *P. gunnii* showed higher use did possess a tussock forming grass species (*Stipa* sp.) which were formerly important in providing shelter in mainland *P. gunnii* (Seebeck 1979). Hence, possibly animals were trapped in habitat preferred for shelter. Structural variation between groups did not appear to reflect trappability of *P. gunnii* or *I. obesulus* on this site (see Tables 9.1.3.2.e-f).

The significantly greater use of floristic group FA on the heath site would not appear to have any dietary function exempting the occurrence of Monocot, in particular *Agrostis capillaris*, of which seeds were detected in scats. The Brown Bandicoots were possibly responding to inundation of trapping stations of other groups during winter and spring months. Most traps in floristic group FA, and the unassigned quadrat, were slightly elevated and hence not inundated during the study. Braithwaite and Gullan (1978) observed *Rattus lutreolus* to change habitat selection with season, associated with flooding leaving sedge leaf bases inaccessible, to a less-preferred area of improved food resources quality. Insect larvae, fungi etc. may become inaccessible in the soil at Huonville with raising of the water table during winter and spring.

The low capture rate in group FC appears to indicate avoidance of this low floristically diverse category (pasture and adjacent heath quadrats). This would be consistent with the observation of Heinsohn (1966) and Gordon (1974a) that Brown Bandicoots prefer low dense ground cover sufficiently open to permit free movement and are rarely caught in areas showing short, grazed grass (Gordon 1971). Structural groupings hinted this view with low captures recorded for group SB (see Table 9.1.3.2.e).

The problems of predicting small mammal habitat use by associations with floristic and structural groups in specific areas are substantial and have been well documented by Hall and Lee (1982). The usefulnes of these techniques in depicting small mammal abundance appears to be dependent on heterogeneity of the area, and on resolution of floristic and structural descriptions relative to the animals' specific requirements.

The limiting ability to predict the microhabitats of *I. obesulus* and *P. gunnii* in the present investigation possibly arises from three factors:

1. *Isoodon obesulus* is caught in a wide variety of macrohabitats, hence specific microhabitats are possibly unimportant in defining habitat preference.

2. Neither species appear restricted by structural microhabitats, but macrohabitat (e.g. open and dense) preferences may prevail.

3. The data, in particular for *P. gunnii*, is very limiting. Approximately 60 captures are dispersed over three study sites, hence restricting analysis to simple statistical tests.

A more comprehensive investigation should be undertaken similar to that of Hall and Lee's (1982), using regressions and other tests to establish relationships between captures and structural and floristic complexity of vegetative groups. However, with such an apparent macrohabitat preference, further differences may fail to evolve. Although,

Braithwaite and Gullan (1978) consider when structural classification provides better resolution of habitat preference, animals may be selecting for cover to avoid predators, competitors or climatic factors. Floristic groups possibly demonstrate floristic composition of food resources, although these may also be correlated with structural characteristics (Braithwaite and Gullan 1978). Hence microhabitat preferences may still prevail within a larger preferred macrohabitat due to selection of cover/food resources.

Furthermore, similarities within groups between study sites could be investigated. This was not practical within the limits of the present investigation. A grid was not established on the golf course site. Hence groupings probably do not reflect the true nature of the vegetation. Heterogeneity may be further demonstrated by a grid system on this site.

CHAPTER 10

GENERAL DISCUSSION AND CONCLUSION

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A popular tenet of community ecology postulates that sympatric species must differ in their exploitation of limiting resources to tolerate co-existence. A non-limiting resource may, however, be utilised by similar species (Hutchinson 1959; Hardin 1960; MacArthur and Levins 1967). Although competitive interaction can only be conclusively attained through manipulative experiments (Grant 1972, 1978), evidence to date suggests that the closely related species, *Perameles gunnii* and *Isoodon obesulus* occupy similar ecological niches in sympatry.

Results pertaining to olfactory trials (Chapter 3) are consistent with Heinsohn's (1966) and Moloney's (1982) observations that bandicoots appear to locate prey via olfactory senses. However, the importance of hearing in prey detection for *P. gunnii* could not be totally overlooked. The absence of a significant difference for *I. obesulus* with respect to the number of earthworm scented cups located, may indicate that this item is of less importance in the diet of wild *I. obesulus* than *P. gunnii*. Digestibility trials (Chapter 4) disclosed that earthworms may be overlooked in faecal analysis due to total digestion of soft-bodied prey. Hence, the importance of earthworms in the diets of both bandicoot species could not be assessed (Chapter 7).

The depth that bandicoots located earthworm and cockroach extracts was 3.5 cm with the exception that *I. obesulus* failed to locate earthworm extract at 3.5 cm (the greatest depth examined). Buchmann (unpublished) considers that *I. obesulus* excavations are considerably deeper than those of *P. gunnii*, hence it is possible that the olfactory senses work to a greater depth for one species and that the two bandicoots are selecting prey from the soil at different depths. Consistent with this view is the finding of Braithwaite and Gullan (1978) that habitat selection by *I. obesulus* on Victorian heathland appeared independent of soil hardness. However, they did not study the response of *P. gunnii* to soil hardness. Furthermore, prey species emitting stronger odours

to the human nose (e.g. cockroach) appear more likely to be detected than those emanating weaker odorous cues (e.g. earthworm).

Digestive tract morphology (Chapter 8) of the two species appeared very similar and compatible with the typically omnivorous digestive systems of bandicoot guts displayed previously in the literature.

Within the limitations imposed by the differential digestibility of food items, the diet of *I. obesulus* and *P. gunnii* at Huonville appeared to be similar (Chapter 7), and the two species appeared ecologically inseparable by such criterion. A majority of comparisons between species were restricted to the total diets because of the small sample size collected for *P. gunnii*, however seasonal variation was attained for *I. obesulus*.

Of the total diets (Chapter 7.1.4), Scarabaeidae larvae, Calliphoridae larvae, spiders and mature Coleopterans were detected in more scats than other prey categories for both bandicoot species. However, when the diets were considered separately, ants (Formicidae) and armyworm caterpillars (Noctuidae) respectively, occurred in a greater incidence of faeces of *I. obesulus* and *P. gunnii* than other categories. Seeds, Monocot (grasses) and what appeared to be Clover root nodules were consumed consistently throughout the year by both species, hence, were reflected in the total diets. Two significant differences between the Peramelid species emerged: the higher frequency of faeces of *I. obesulus* containing bees and wasps (Hymenoptera), and of *P. gunnii* scats containing Clover.

The most important invertebrate items detected in faeces of *I. obesulus* in autumn (Chapter 7.1.5) were ants, Calliphoridae larvae, Rove beetles (Staphylinidae), mature Coleopterans, Hemipterans, Hymenopterans and Scarabaeidae larvae. Those of *P. gunnii* were larvae, spiders (Araneae), flies (mature Diptera), Calliphoridae larvae, ants, ground beetles (Carabidae) and their larvae. Scats were often burdened with blackberries (*Rubus fruticosus*), while Monocot and the mycorrhizal fungi (Zygomycote) were important components in faecal pellets of both species. Moss was extremely important in the small number of *P. gunnii* scats,

but less so in *I. obesulus*.

Only two faecal pellets were collected for *P. gunnii* in winter hence will not be considered here. Scarabaeidae larvae, ants, Carabidae larvae, mature Coleopterans and armyworm caterpillars occurred in more scats of *I. obesulus* in winter, relative to other food categories, while seeds, Monocot, root nodules, Gasteromycete and Zygomycete fungus were recorded from the plant component in the greatest occurrence of faeces. Hepialidae (Corbie grubs) declined and were not detected.

Spiders and Corbie grubs compared to other prey categories were encountered in the highest frequency of faecal pellets in spring of *I. obesulus* with Rove beetles, E/S/C larvae, Carabidae beetles, Hemipterans, ants and mites (Acarina). Scarabaeidae larvae appeared to become less important. Zygomycete fungus decreased in frequency, although unidentified fungus was detected more often relative to other categories. Seeds, Monocot and root nodules remained important. Five samples for *P. gunnii* revealed Noctuidae larvae, Scarabaeidae larvae, E/S/C larvae, mature Coleoptera to be detected in more faecal samples than other prey groups; E/S/C larvae appeared to increase with increasing availability. For the plant component, Monocot and seeds occurred in more scats while roots increased in importance for *P. gunnii* relative to other prey groups.

Slight differences in diet between habitats (Chapter 7.1.7) were observed for *I. obesulus*. In some instances, these appeared to be related to a wider prey range available on the wet heath site and in other instances to the local availability of prey.

The selection of a wider range of prey on the heath site by female Brown Bandicoots possibly reflects the greater demand for protein requirements by these lactating females. Evidence from the present investigation, Heinsohn (1966) and Moloney (1982) would suggest that food supply and hence rain may have an extremely important effect on reproduction in Tasmanian bandicoots. Above average rainfall over summer months possibly delayed the ending of the breeding season in this study.

A large number of discrepancies were apparent between the frequency of faecal samples containing prey taxa and the oft'ness of pitfall traps or soil samples exhibiting those categories (Chapter 7.1.6). In some cases, these appeared to be an artefact inherent in the technique of pitfall trapping or soil sampling. However, some disparities appeared to eventuate from bandicoot food preference e.g. Amphipoda and the possibility of soft-bodied animals abundant in pitfall traps being totally digested in faeces.

The bandicoots could not possibly be considered to fulfil the quantitatively opportunistic definition (eating prey taxa in proportion to which they occur) with such a large number of disparities. However, *I. obesulus*, in particular appears to fulfil the qualitatively opportunistic definition utilised by Hall (1980b), Statham (1982), Fox and Archer (1984) by virtue of the fact that they appear to select food from almost the entire range of prey available to them. In this sense the term "generalist omnivore" appears applicable to the two species.

Moloney (1982) considered bandicoots to be ecological equivalents of the eutherian hedgehogs (see Brockie 1959) and shrews (see Pernetta 1976) in that they appear to fulfil similar niches excavating for insects in the soil during darkness, and retiring in daytime nests.

Braithwaite *et al.* (1978) suggested that the small mammal communities in the heathland and forests of south-eastern Australia are organized around five major food niches. They further considered that *I. obesulus* occupied the soil fossicking insectivore niche and in certain situations, *Antechinus minimus* and *I. obesulus* or *Potorous tridactylus* may co-exist. Evidence from the present investigation suggests that *P. tridactylus*, *I. obesulus* and *P. gunnii* co-exist and occupy very similar niches in certain areas. Dietary analysis of three *P. tridactylus* faecal pellets collected from the wet sclerophyll forest-open pasture site in autumn revealed essential similarities to those of *I. obesulus*, with Blackberry seeds and skins dominating the diet, small amounts of Monocot and fibrous roots, the Hymenogaster type Gasteromycete fungus, the unidentified brown spores, Zygomycete fungus (*Endogone*), seeds, invertebrates and larvae (Hemipterans, Calliphorid and Chironomid larvae,

and spiders). Examination of three scats of *P. tridactylus* trapped behind the University also displayed similarities to *P. gunnii* faeces collected there. These predominantly displayed Moss, Monocot and insect remains. The insect remains persisted digestion in a more fuller state suggesting that *P. tridactylus* may be more herbivorous than the bandicoots. Heinsohn (1968) suggested that bandicoots were more insectivorous than *P. tridactylus*.

In terms of Hutchinson's (1959) niche theory, food resources may be non-limiting, hence, in effect, bandicoots, and potoroos may not be competing. Consistent with this is the observation that the bandicoots are utilising a wide array of food categories, hence competition may be minimal. Moloney (1982) considered that the wide range of prey used by *P. gunnii* and *I. obesulus* may significantly reduce competition. However, a comparison between the diets of bandicoots and potoroos in sympatry warrants further investigation. A similar diet was reported for the Eastern Native Cat (*Dasyurus viverrinus)*, but Godsell (1983) suggested the fact that *D. viverrinus* does not excavate in the soil may significantly reduce competition between the Peramelids and this Dasyurid.

Lee and Cockburn (1985) have divided marsupial principal food types into 10 feeding categories. The bandicoots at Huonville appear to span a variety of these categories including insectivore/omnivore, fungivore/omnivore, frugivore/omnivore and frugivore/granivore. Furthermore, dietary categories are consistent with what is known of bandicoot diet in general (see Chapter 7.1.1) including invertebrates, fruit, fungus, grass and seeds.

Natural selection favours genotypes which encourage their owners to select food items yielding greatest net energy and nutrients required to find, capture and devour food items (Emlen 1968). Hence, an animal having higher efficient energy consumption can devote more time and energy to reproduction, enhancing survival of offspring (Schoener 1971). Natural selection therefore achieves optimal allocation of time and energy expenditure (Pulliam 1974).

The optimal diet minimizes total search, pursuit and handling time, per food item captured (MacArthur and Pianka 1966) and maximizes food value per unit foraging energy (Tullock 1971; Elner and Hughes 1978). The premise assumes predators rank prey types (and sizes) according to their value (Emlen 1968; Griffiths 1975). Two sources of evidence relating to insect prey size (Chapter 7.2) are consistent with *I. obesulus* foraging optimally:

(1) Significantly larger prey sizes appeared to be consumed in comparison to that available in pitfall traps and soil samples suggesting smaller, less profitable prey may be bypassed.

(2) During winter, this size difference is not as pronounced coinciding with an apparent increased availability of small prey.

Krebs (1977) postulates that predators should be less selective when food is scarce. Hence, the inclusion of smaller, less profitable prey in winter may relate to scarcity of larger prey.

Although predominantly selecting larger prey size classes, the observation that predator size reflects prey size was not apparent. Perhaps a variable parameter such as body weight is not a precise indicator of dietary niche separation. However, assuming prey sizes determined by insect tarsal widths are accurate, to state that bandicoots select prey in proportion to a morphological character relating to the predator's body size would contradict the opportunistic term applied to these animals. *Isoodon obesulus* possibly selects the first food item above a certain size encountered.

Schoener (1974) suggests that species achieve ecological segregation spatially, temporally and by selection of food resources. The first two dimensions appear most important, assuming the bandicoots are competing.

Precise diel activity of *P. gunnii* and *I. obesulus* was not established (Chapter 6), however, the diurnal activities displayed by *I. obesulus* may significantly reduce competition (*P. gunnii*

appeared to be strictly nocturnal).

Although not disclosed in trapping results (Chapter 6), a combination of live-trapping conclusions and spotlighting data appeared to show that *P. gunnii* extensively utilized open habitats while *I. obesulus* appeared to prefer denser vegetation although were captured in open areas. Morphological differences in sympatric animals have been shown to exist and usually niche segregation relates to the size of a feeding apparatus (Ashmole 1968). Hutchinson (1959) demonstrated the feeding apparatus to differ in size by a factor of 1.2 to 1.4 which can be related to the use of a limiting resource.

In the present investigation morphological adaptation appears more likely to reflect structural adaptations for use of a habitat which accords with niche spacing rather than feeding apparatus. The apparent little difference in diet appears to suggest that the difference in snout length as reflected in head length measurements (Heinsohn 1966; Moloney 1982) is not important in separating the two species, although one species may excavate deeper than the other. Instead the stout body size of *I. obesulus* may better adapt it to foraging in denser habitats relative to the lighter, slender build of *P. gunnii* which allows rapid escape from predators in open situations.

The Barred Bandicoot appeared to be absent from the regenerating heath site (Chapter 6) suggesting either that unlike *I. obesulus*, *P. gunnii* is unable to exploit regenerating heath or that in situations where open areas e.g. pasture are present near regenerating stands e.g. burned areas or cleared sites, *P. gunnii*, in the presence of *I. obesulus*, may select the former. The overall result may effectually reduce competition. Habitat preferences would appear important in ecologically segregating microtine rodents (see Cameron 1964; Morris 1969; Douglas 1976).

Few microhabitat parameters were defined by the vegetation analysis undertaken in the present study. The possible explanations for this have been discussed in Chapter 9.1.4. Macro-habitat selection would appear to be more critical.

The alternative contention (to the niche concept), most convincingly postulated by Strong *et al.* (1979), Rotenberry and Wiens (1980), Wiens and Rotenberry (1981), amongst others, states that biotic interactions e.g. competition, although apparent, may be of only minor importance in organising community structure. Hence, many ecological communities are not at equilibrium, and their composition is determined by interactions of factors e.g. evolutionary, biogeographical and ecological.

The situation may bear particular relevance to Australian mammals, for sclerophyll heathlands and *Eucalypt* forests are frequently burned, and the view that much of the Australian vegetation is adapted to sustain fire is consistently held (Gill 1975). Changes in floristic composition and productivity follow disturbance (Jones *et al.* 1969) and several species of mammals have been shown to respond to these changes (e.g. Christensen and Kimber 1975; Newsome *et al.* 1975; Cockburn 1978; Cockburn *et al.* 1981; Fox and McKay 1981; Fox 1982a, 1982b). Long-term survival and co-existence for some mammals would appear dependent on fire frequency and intensity (Cockburn *et al.* 1981; Fox 1982b) and Fox (1982a) discusses possible mechanisms by which fire may alter mammalian community structure. Hence, Australian mammal communities may fail to ever reach equilibrium.

The role of *Isoodon* spp. occupying early seral successional stages following fire (Heinsohn 1966; Newsome *et al.* 1975; Fox 1982a; Moloney 1982) and clearing (Stoddart and Braithwaite 1979; Opie 1980; present investigation) has been demonstrated. The Long-nosed Bandicoot (*Perameles nasuta*) has additionally been shown to respond to early post-fire stages (Newsome *et al.* 1975). The response of *P. gunnii* to perturbed habitats following burning/clearing is not known. However, evidence to date would suggest that *P. gunnii* does not colonise early pyric successional stages (Heinsohn 1966; Moloney 1982), or early man-induced successional changes (present investigation) in as greater frequency as *I. obesulus*. The paradox may be disclosed by long-term trapping of a disturbed site.

In conclusion, considering the fact that soft-bodied prey may be totally digested, faecal analysis revealed *I. obesulus* and *P. gunnii* at Huonville to select a similar, wide range of prey. The extensive array of food items may result in the resource exceeding the bandicoots' capabilities to harvest it. However, differences may arise in summer (not examined) when food is likely to be more limiting. Assuming competition, diet (prey type and size) and foraging strategies did not appear to ecologically separate the two species. The diet largely appeared to reflect seasonally and locally abundant food resources. Stable co-existence may appear to resolve from macro-habitat selection and different periods of activity.

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APPENDICES

APPENDIX A

DISTRIBUTION AND ABUNDANCE OF *Perameles gunnii* AND *Isoodon obesulus* AS SHOWN BY THE "TASPAWS" BIOLOGICAL RECORDS SCHEME

The Tasmanian National Parks and Wildlife Service regularly conduct road-kill surveys for monitoring population and abundance of Pademelons, *Thylogale billardierii*, and Brushtail Possums, *Trichosurus vulpecula*. Trends in the density of animals are assessed.

In addition, *P. gunnii* and *I. obesulus* sighted during surveys are recorded. Inaugural surveys involved accumulation of data from road kills recorded along short sections of the state highways adjacent to various habitat formations. However, from 1977-1982 quarterly replicate surveys were undertaken along 12 standard transects of state highway totalling 1845 km. The transects include areas containing a majority of habitat types present in Tasmania. Additionally, vegetation, topography, altitude and soil composition are occasionally noted for the sites where carcasses are found. Information procured from surveys is stored in a computer headed "TASPAWS" Biological Records Scheme. In addition, records are received from the general public.

The distribution and relative abundances are biased towards human population centres and the state highways surveyed. However, in obtaining crude information on the status and distribution of *I. obesulus* and *P. gunnii* the scheme harvests useful data.

The location of survey transects, the distribution and relative abundances of *P. gunnii* and *I. obesulus* for the period 1967-1984 are presented in Figs. A1 and A2 respectively. Additional records which increase the species range and fossil records are also shown. These records are likely to be the most reliable information source, hence are employed to demonstrate the bandicoots' status. Moloney (1982) gives a fuller account of the "TASPAWS" scheme and some of the changes

in bandicoot abundance which have taken place during the scheme's operations.

The approximate limits of distribution of *I. obesulus* and *P. gunnii* in Victoria are also given (A3) from Seebeck (1979).

FIGS. A1 and A2 Distribution and relative abundance of *P. gunnii* (A1) and *I. obesulus* (A2) in Tasmania as depicted by "TASPAWS" Biological Records Scheme from 1967-1984 (heavy lines indicate transect surveys).

Number of records *P. gunnii* 1056

I. obesulus 852

Key observations

■ 1-6

● 7-20

▲ 21-60

○ Additional non-roadkill records which increase the species range

□ Non-"TASPAWS" records which increase species range

△ Fossil Records

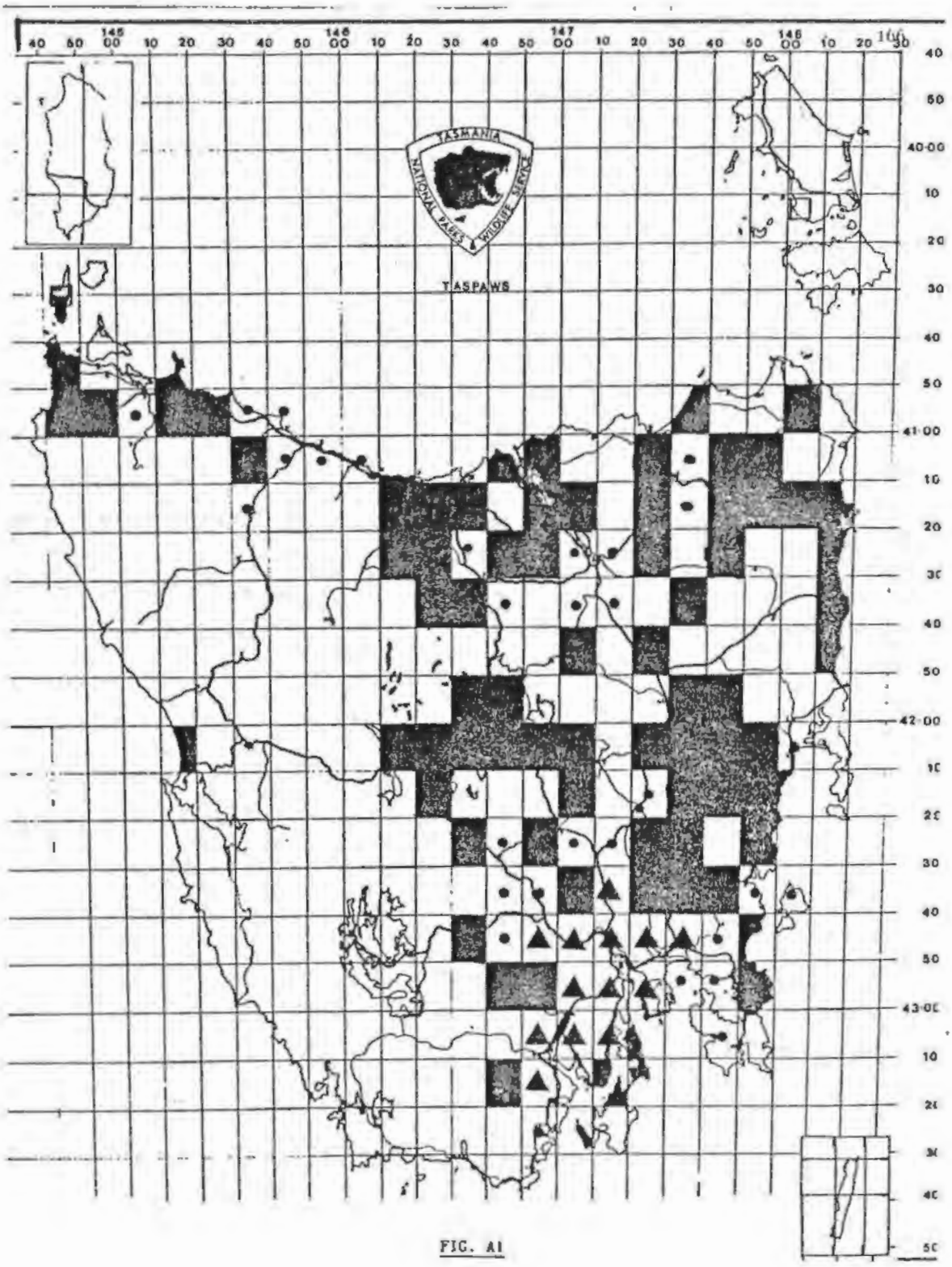


FIG. A1

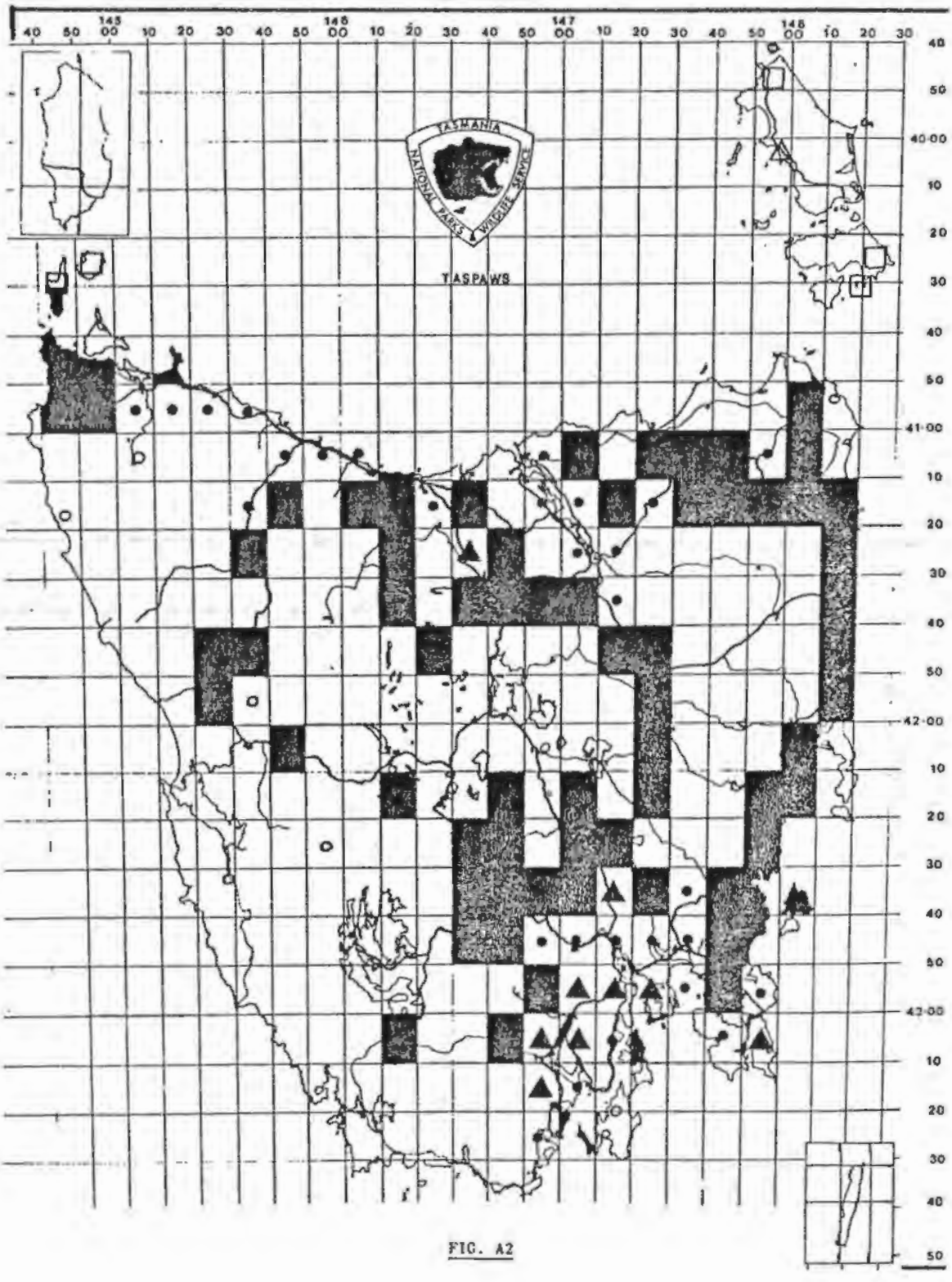


FIG. A2

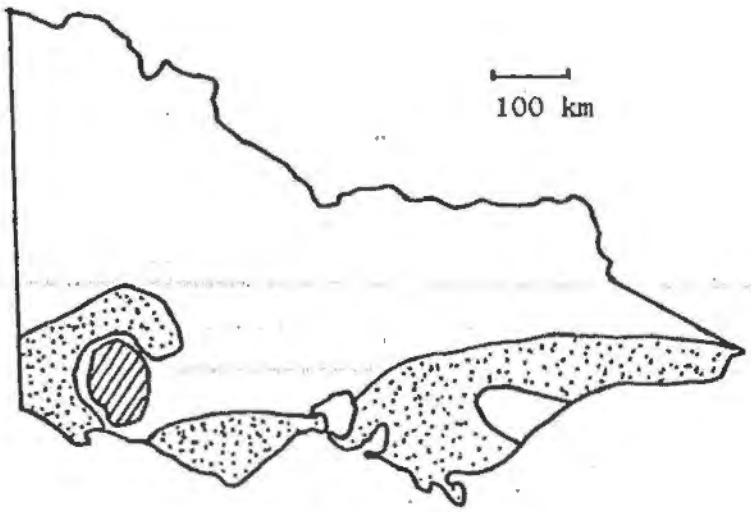


FIG. A3 Approximate limits of distribution of *Perameles gunnii* and *Isoodon obesulus obesulus* in Victoria, 1977.
(From Seebeck 1979)

APPENDIX B

INAUGURAL AND SUBSEQUENT TRAPPING SESSIONS IN UNIVERSITY (HOBART) AREA

TABLE B.1 Initial trapping results for Proctor's Road locality.

Date	Species Recorded	Number of Trap Nights	Captures per Trap Night
15/3/85	*Rattus norvegicus*	10	0.2

TABLE B.2 Initial and subsequent trapping results for the enclosure at University rear and surrounding area.

Dates	Species Recorded	Number of Trap Nights	Captures per Trap Night
9-18/3/85	*Potorous tridactylus apicalis*	42	0.26
	Trichosurus vulpecula	42	0.14
	Perameles gunnii	42	0.07
4-9/8/85	*Potorous tridactylus apicalis*	30	0.43*
	Perameles gunnii	30	0.03

* 3 captures carrying a single pouch young

APPENDIX C Botanical list of the plant species collected from the three study sites (x - indicates recorded on that study site)

	Study Site		
	1	2	3
BRYOPHYTA			
Lembophyllum divulsum (Hook. f. et Wils.)	x	x	x
Brachythecium sp.		x	
Ptychomnion aciculare (Brid.)	x		
PTERIDOPHYTA			
Pteridium esculentum (Forst. f.)	x	x	
MONOCOTYLEDONEAE			
Cyperaceae			
Carex sp.	x		
Gahnia sieberiana Kunth.	x		
Lepidosperma elatius (Labill.)	x	x	x
Schoenus apogon (Roem. & Schult.)		x	x
Schoenus tesquorum (Black)			x
Gramineae			
Agrostis capillaris		x	x
Agrostis sp.	x		
Bromus sp.		x	x
Cynodon dactylon (L.)		x	x
Dactylis glomerata	x		
Microlaena sp.		x	x
Poa annua (L.)	x		
Poa poiformis (Labill.)		x	x
Poa tenera (F. Muell.)	x		
Stipa sp.		x	x
Unidentified grass sp. 1		x	x
Juncaceae			
Juncus australis (Hook. f.)	x	x	x
Liliaceae			
Lomandra longifolia (Labill.)		x	x
Restionaceae			
Restio complanatus		x	x
DICOTYLEDONEAE			
Baueraceae			
Bauera rubioides Andr.		x	
Compositae (Asteraceae)			
Cassinia aculeata (R. Br.)	x	x	x
Cirsium vulgare (Savi) Ten.	x		
Crepis capillaris (L.) Wallr.	x		
Hypochaeris glabra (L.)	x	x	x
Hypochaeris radicata (L.)		x	x
Olearia floribunda (Hook. f.)		x	x
Dilleniaceae			
Hibbertia empetrifolia (DC.) Hoogl.		x	x
Droseraceae			
Drosera sp.			x

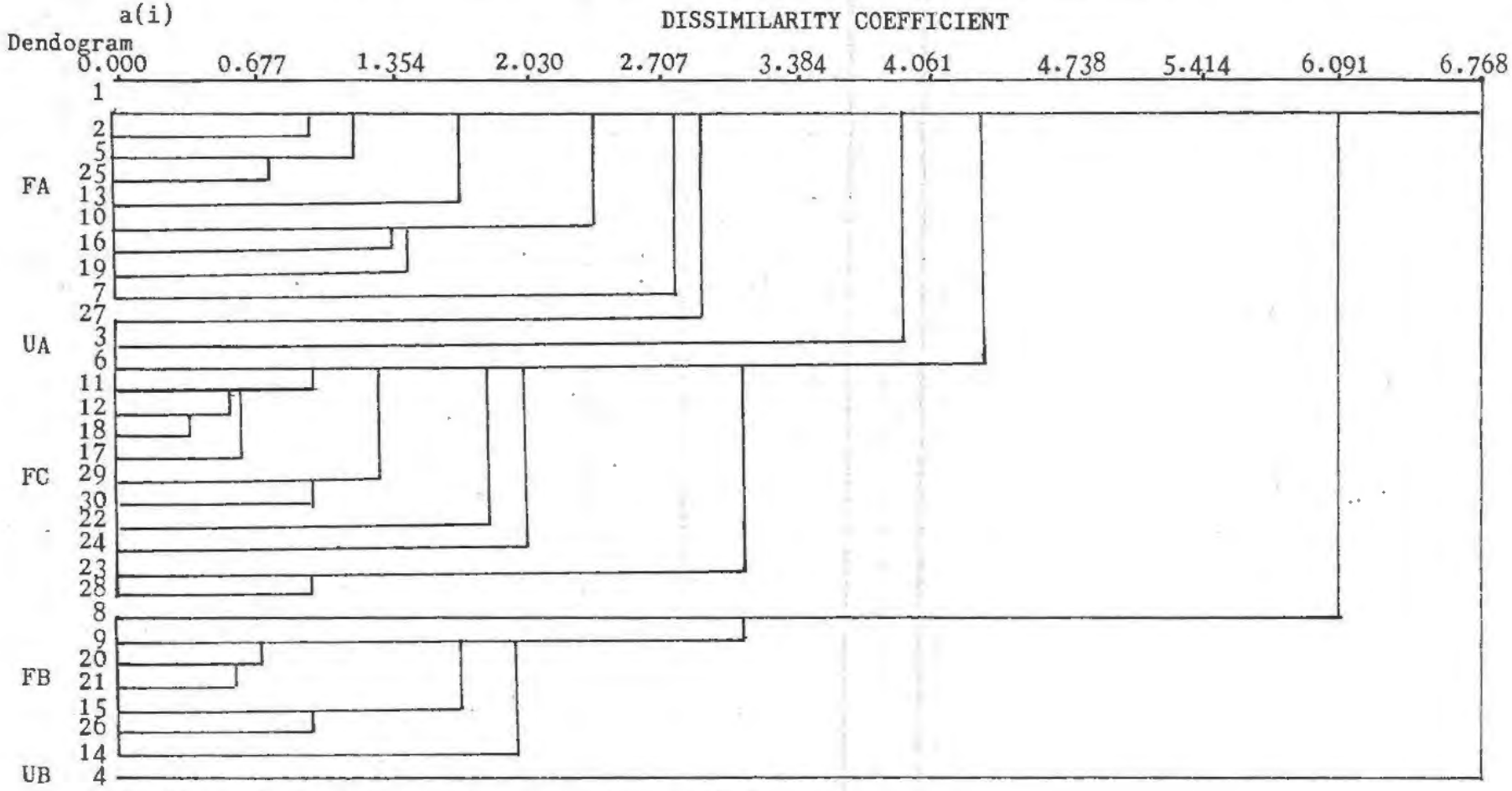
APPENDIX C (cont'd)

	Study Site		
	1	2	3
Epacridaceae			
Epacris impressa Labill.		x	x
Epacris lanuginosa Labill.		x	x
Styphelia adscendens R. Br.		x	x
Ericaceae			
Erica lusitanica Rudolp.		x	
Geraniaceae			
Geranium potentilloides L'Hérit. ex DC.	x	x	x
Goodeniaceae			
Goodenia ovata Sm.			x
Haloragaceae			
Haloragis tetragyna (Labill.)		x	x
Hypericaceae			
Hypericum japonicum Thunb. ex Murr.		x	
Labiatae			
Prunella vulgaris L.	x		
Malvaceae			
Asterotrichion discolor (Hook.) Melville	x		
Mimasoceae			
Acacia dealbata Link.	x	x	
A. melanoxylon R. Br.	x		
A. stricta (Andr.) Willd.		x	x
A. verticillata (L'Hérit.)	x	x	x
Myrtaceae			
Eucalyptus obliqua L'Hérit.		x	
E. ovata Labill.	x	x	x
Leptospermum scoparium J.R. & G. Forst.	x	x	x
Melaleuca squarrosa Donn & Sm.	x	x	x
Oxalidaceae			
Oxalis corniculata L.			x
Papilionaceae			
Lotus corniculatus L.	x		
Pultenaea juniperina Labill.		x	
P. stricta Sims.		x	x
Trifolium repens L.	x	x	x
Vicia sp.	x		
Plantaginaceae			
Plantago lanceolata L.	x	x	x
Polygonaceae			
Rumex sp.	x		
Ranunculaceae			
Ranunculus repens L.	x		
Rhamnaceae			
Pomaderris apetala Labill.	x		
Rosaceae			
Acaena novae-zelandiae Kirk	x		
Potentilla anglica Laicharding	x		
Rubus fruticosus L.	x	x	x

APPENDIX C (cont'd)

	Study Site 1	2	3
Rubiaceae			
Coprosma quadrifida (Labill.)			
Vent.	x		
Santalaceae			
Exocarpus cupressiformis Labill.	x		
Umbelliferae			
Hydrocotyle hirta R. Br. ex A. Rich.			x

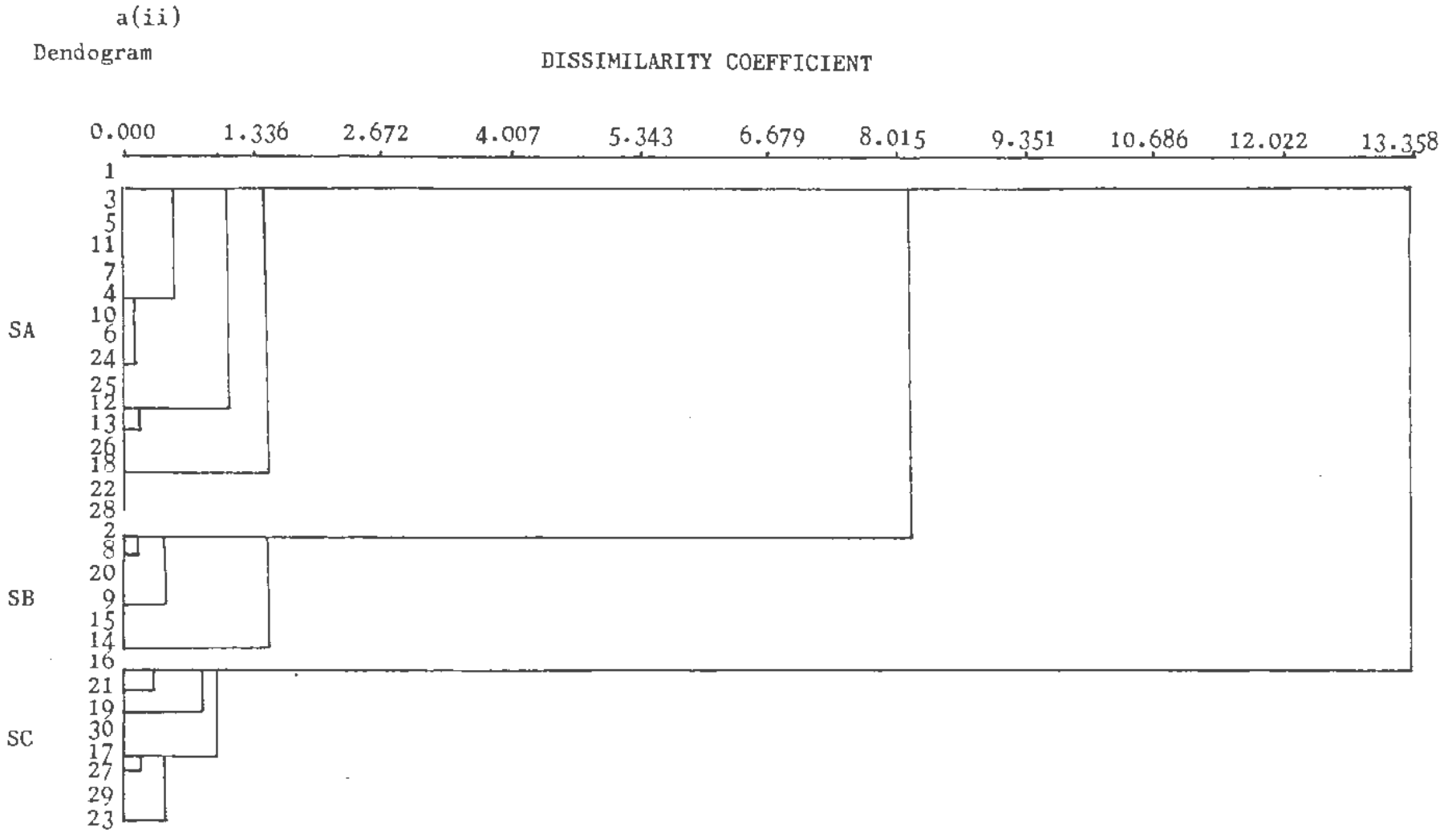
APPENDIX D Dendogramatic representation of (i) floristic and (ii) structural classification of vegetation on (a) wet slerophyll forest-open pasture, (b) regenerating wet sclerophyll-golf course fairways and (c) wet heath-pasture study sites using Ward's minimum sum of squares method (see text, Chapter 9.1.2.2.b for explanation).



Ward's method (minimum S.S.) wet sclerophyll forest-open pasture.
Floristic data normalised by quadrat.

a(ii)

Dendogram

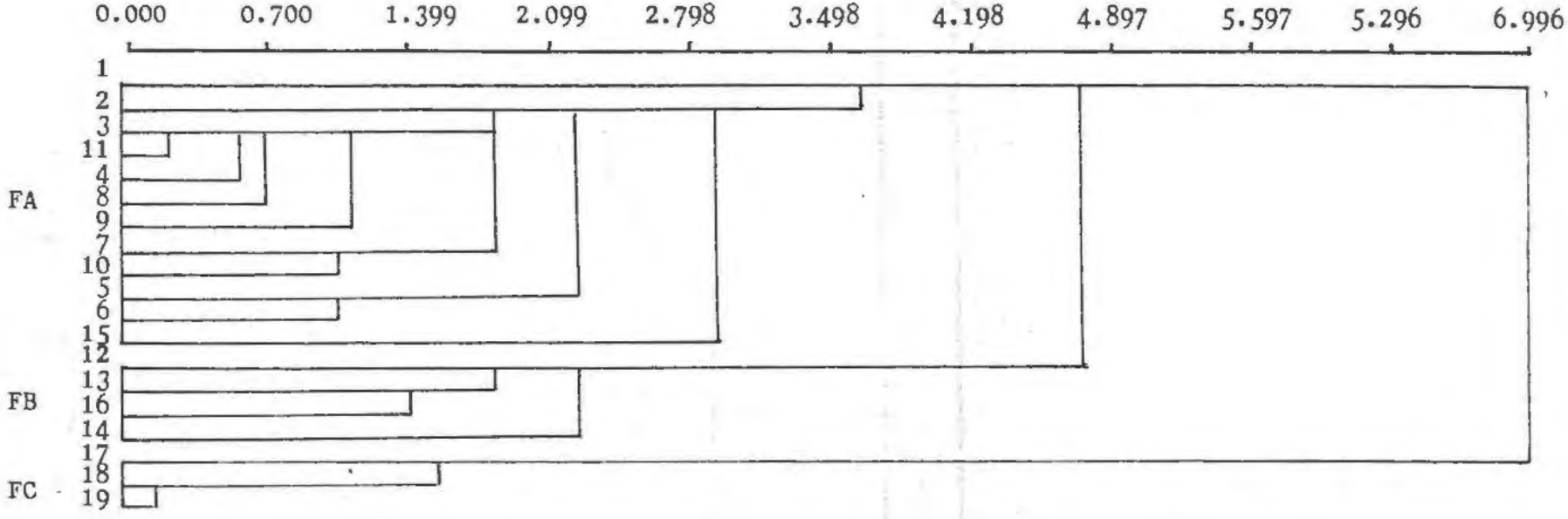


Ward's method (minimum S.S.) wet sclerophyll forest-open pasture.
Structural data normalised by quadrat.

b(i)

Dendogram

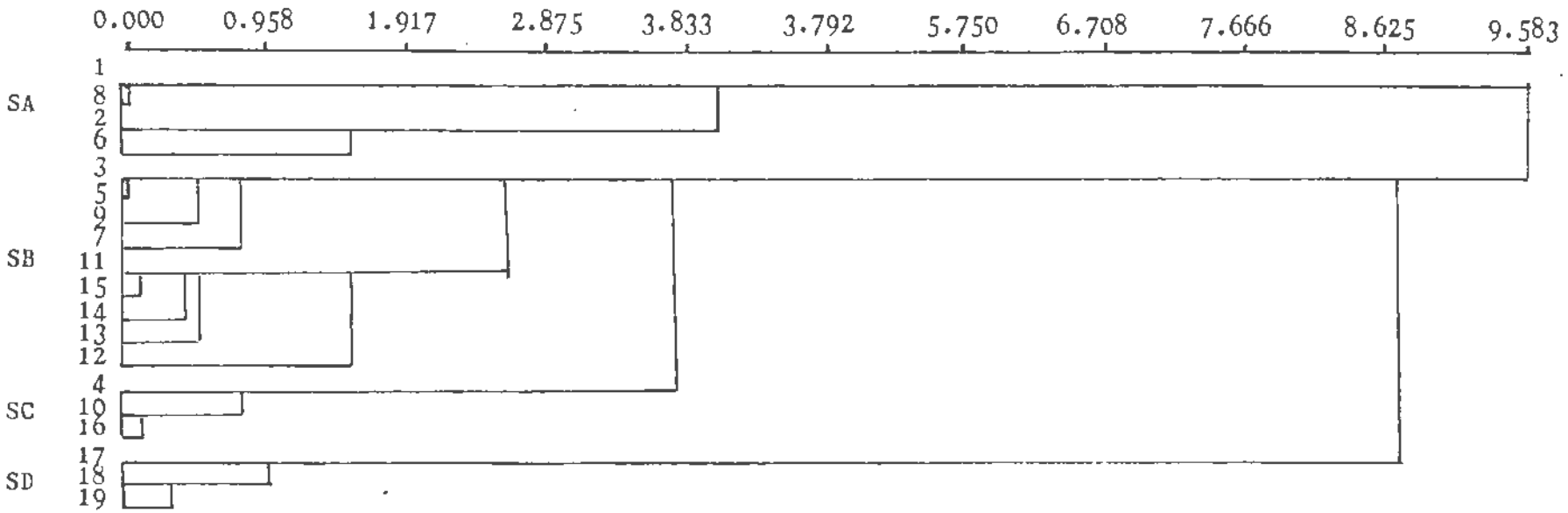
DISSIMILARITY COEFFICIENT



Ward's method (minimum S.S.) regenerating wet sclerophyll forest-golf course fairways.
Floristic data normalised by quadrat.

b(ii)

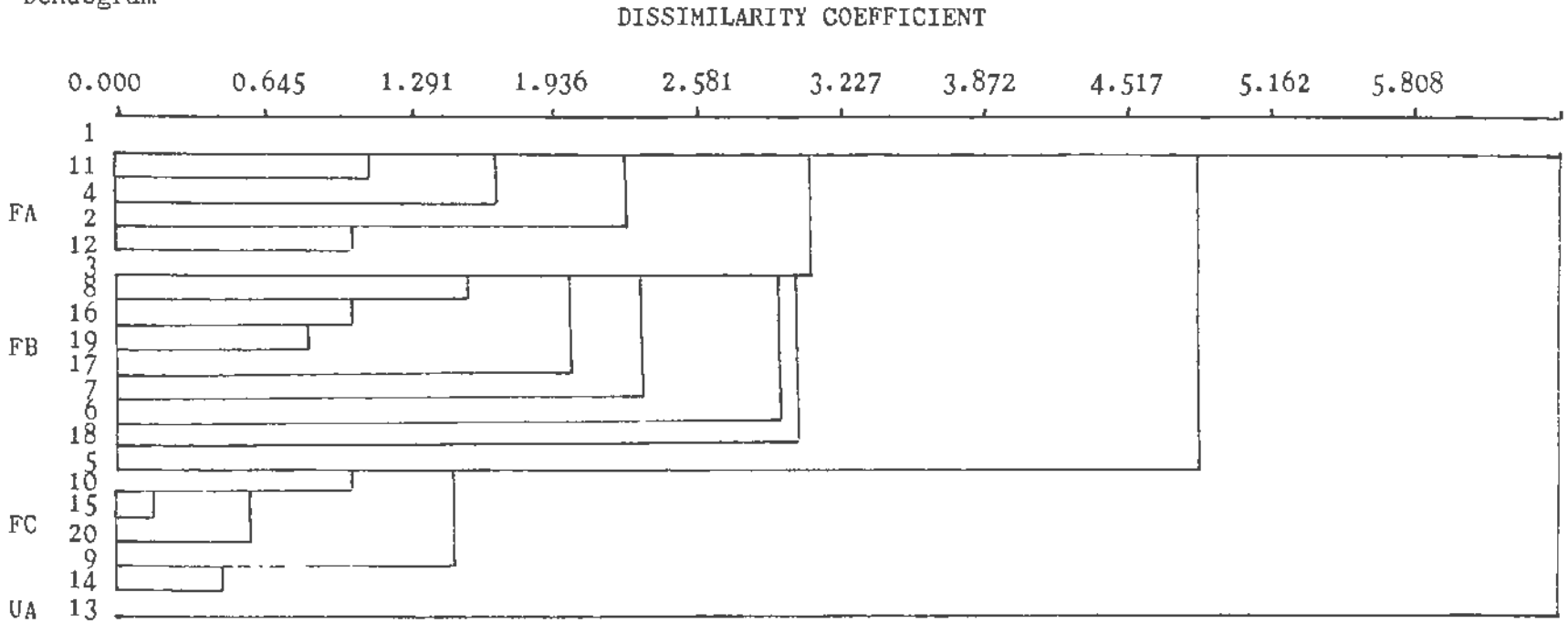
Dendogram



Ward's method (minimum S.S.) regenerating wet sclerophyll forest-golf course fairways.
Structural data normalised by quadrat.

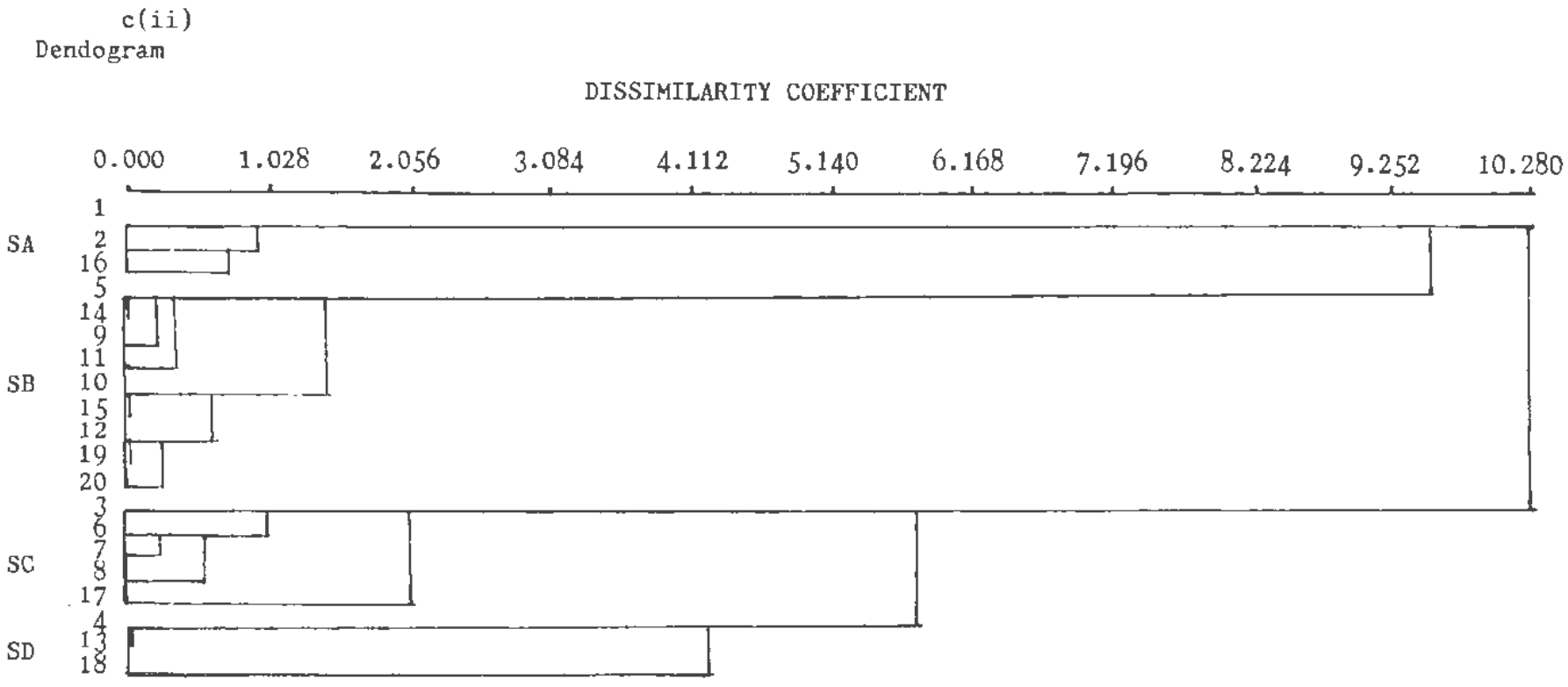
c(i)

Dendogram



Ward's method (minimum S.S.) wet heath-pasture.
Floristic data normalised by quadrat.

c(ii)
Dendogram



Ward's method (minimum S.S.) wet heath-pasture.
Structural data normalised by quadrat.

NATIONAL PARKS AND WILDLIFE SERVICE

MAGNET COURT
OR P.O. BOX 210,
SANDY BAY, TAS. 7005
TELEGRAMS: TASPAWS

ADDRESS ALL CORRESPONDENCE
TO THE DIRECTOR
PHONE 30 8033 EXTN
INQUIRIES MR
PLEASE QUOTE

File No. W6/4

Permit No. 85/35

SPECIAL PERMIT TO COLLECT AND POSSESS SPECIMENS OF PROTECTED WILDLIFE (LIVE OR DEAD) FOR SCIENTIFIC RESEARCH PURPOSES

Pursuant to the provisions of Section 35 of the National Parks and Wildlife Act 1970. Approval is hereby granted

TO Mr. D. Quinn, Mr. R. Mawby, Prof. D.M. Stoddart, C/- Department of Zoology, University of Tasmania, G.P.O. Box 252C, Hobart

to collect and possess the specimens listed below, subject to the following conditions:

1. None of the material collected shall be made permanently available* to other persons unless with the written approval of the Director.

2. A report showing details of all specimens collected is to be forwarded to the Director within seven (7) days of the expiry of this permit.

3. Copies of reports of investigations to be provided to the Director on completion of the study.

4. This permit is not valid for collecting in State Reserves or conservation areas.

5. This permit may be immediately revoked upon breach of any of the above conditions and must be produced on demand by an authorized officer.

6. Special Condition

Five specimens of each species to be held at the University are to be released at the trap site immediately following completion of the study.

DESCRIPTION OF AUTHORITY

1. To live trap and release barred bandicoot and brown bandicoot.
2. To possess up to five (5) only of each species (see condition 6 above).

Expiry Date ....31.12.85.....

Issued by ...A.Hamilton.....
for P. Murrell, Director

Date of Issue 13.3.85

SEE OVER FOR FURTHER CONDITIONS

7. The utmost care to be exercised to minimize disturbance to the habitat and environment.

8. All specimens collected to be used for scientific study purposes and not for private collection.

9. All live specimens must be released in the place from which they were originally collected upon completion of study.

* For approval to be granted to lodge permanent reference material in taxonomic or other collections, the specimen numbers and the names of the intended institution(s) and person(s) responsible for the curation of specimens should be supplied on application.

NATIONAL PARKS AND WILDLIFE SERVICE

MAGNET COURT
OR P.O. BOX 210,
SANDY BAY, TAS. 7005
TELEGRAMS: TASPAWS

ADDRESS ALL CORRESPONDENCE
TO THE DIRECTOR
PHONE 30 8033 EXTN
INQUIRIES MR
PLEASE QUOTE

File No. W6/4

Permit No. 86/19

SPECIAL PERMIT TO COLLECT AND POSSESS SPECIMENS OF PROTECTED WILDLIFE (LIVE OR DEAD) FOR SCIENTIFIC RESEARCH PURPOSES

Pursuant to the provisions of Section 25 of the National Parks and Wildlife Act 1970. Approval is hereby granted

TO Mr. D. Quinn, Zoology Dept., University of Tasmania, G.P.O. Box 252C, Hobart

to collect and possess the specimens listed below, subject to the following conditions:

1. None of the material collected shall be made ~~permanently~~ available* to other persons unless with the written approval of the Director.

2. A report showing details of all specimens collected is to be forwarded to the Director within seven (7) days of the expiry of this permit.

3. Copies of reports of investigations to be provided to the Director on completion of the study.

4. This permit is not valid for collecting in State Reserves or Conservation areas.

5. This permit may be immediately revoked upon breach of any of the above conditions and must be produced on demand by an authorized officer.

6. Special Condition

.....

.....

.....

DESCRIPTION OF AUTHORITY

to collect up to 6 specimens only of each of: Brown Bandicoot
Barred Bandicoot

Expiry Date 30 November 1986

Issued by .....
for P. Murrell, Director

Date of Issue 6.12.85

SEE OVER FOR FURTHER CONDITIONS

7. The utmost care to be exercised to minimize disturbance to the habitat and environment.

8. All specimens collected to be used for scientific study purposes and not for private collection.

9. All live specimens must be released in the place from which they were originally collected upon completion of study.

* For approval to be granted to lodge permanent reference material in taxonomic or other collections, the specimen numbers and the names of the intended institution(s) and person(s) responsible for the curation of specimens should be supplied on application.